Post-fire Vegetation Development and Fire Effects in the SBS Zone: Haggen Creek, Francis Lake, Genevieve Lake, Brink, and Indianpoint Sites

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Evelyn H. Hamilton

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ABSTRACT

The effects of clearcutting and slashburning on vegetation and soil composition and structure were monitored at permanent plots in the Prince George Forest District for up to 10 years post-burn. Changes in floristic composition, percent cover, and height were documented and described for each study area. At each site, standard fire weather stations were used to determine fire weather codes and indices and predict forest floor moisture content. Woody fuel loading and consumption and burn severity were determined using a line-intercept approach in standard fire effects assessment triangles and circular plots. Forest floor consumption, mineral soil exposure, and woody fuel consumption were compared to values predicted by the Prescribed Fire Predictor.

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Although clearcutting and slashburning have been widely practised in British Columbia, little is known about subsequent patterns of vegetation development or how management activities, particularly slashburn severity, influence these patterns. In response to this need for further information, several studies were designed to examine this effect in the Prince George Forest District of the Northern Interior Forest Region. Fire effects, vegetation, and conifer seedling responses were monitored for 3–10 years after slashburning in five study sites. The study areas include: Haggen Creek (HC), Francis Lake (FL), Genevieve Lake (GL), Brink (BR), and Indianpoint (IP) (Figure 1). This report summarizes the findings of these studies.

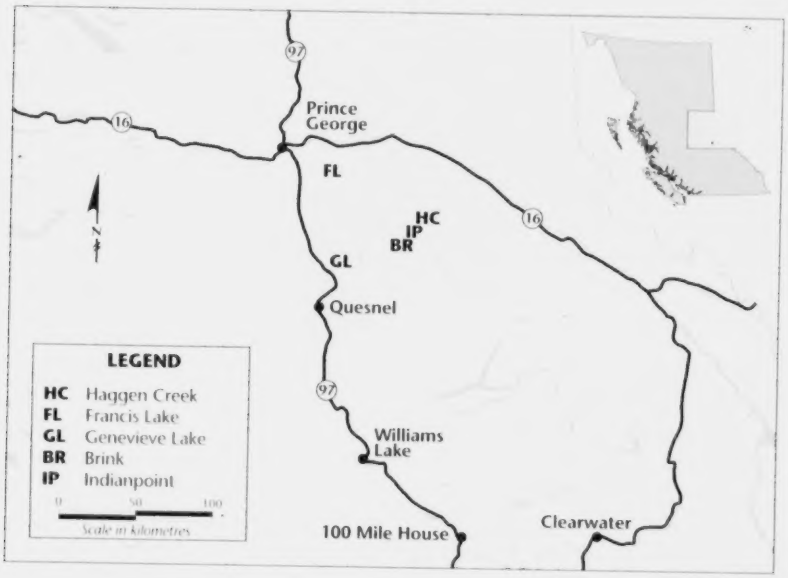

FIGURE 1 *Study site locations.*

Abstract

Fire effects and vegetation and seedling responses to burning were monitored for 3 years after slashburning. Data from a fire weather station were used to calculate fire weather codes and indices. Fuel loading and consumption and burn severity were determined using fire effects assessment triangles. Changes in floristic composition and structure (percent cover and height) were documented, along with growth of planted hybrid white spruce seedlings.

The burn was of moderate severity, with some mineral soil exposure and significant large fuel consumption. Forest floor consumption and mineral soil exposure were less than predicted by the Prescribed Fire Predictor, while fuel consumption was higher than predicted.

After the site was logged and burned, the ground-level vegetation structure shifted to a shrub–herb complex. Most of the original species resprouted after burning. Some of the original forest species were lost. Many new species established from the seed bank and sources outside the plot. One of the distinguishing characteristics of this site was the preponderance of *Rubus parviflorus*, which proliferated from buried seeds and resprouting, achieving a cover of close to 30% the year after burning. Although most of the native vascular species diversity was maintained in the plots, several invasive species established. The resilience of the native vascular species demonstrates that this is a fire-adapted ecosystem.

It was notable that many of the original species on this site were absent or had low cover the year after burning. This suggests that changes in indicator species abundance occur after significant disturbances in this ecosystem type, and this should be kept in mind when classifying sites in early seral stages.

1 INTRODUCTION

1.1 Background

Clearcutting and slashburning have been widely practised in British Columbia, but little is known about subsequent patterns of vegetation development or how management activities, particularly slashburn severity, influence these patterns. Hamilton and Yearsley (1988) provided preliminary models of forest vegetation succession that helped facilitate integration of forest regeneration with wildlife habitat and biodiversity needs in the Sub-Boreal Spruce zone and assisted in the development of a seral classification within the biogeoclimatic ecosystem classification (BEC) system. General information on the autecology of common British Columbia species and their responses to burning is summarized by Haeussler et al. (1990) and the U.S. Forest Service Fire Effects Information System (U.S. Dep. Agric. For. Serv. 2006). To date, there is limited published site-specific information on the response of species to different levels of fire severity in various ecosystems.

This is the final report on the Haggen Creek study (E.P. 1093). This site is one of several in British Columbia where fire effects, vegetation, and tree responses were monitored after clearcutting and slashburning in permanent plots for 3 years or longer.

1.2 Objectives

The objectives of this study are:

1. to document the effects of a prescribed slashburn on the forest floor, fuels, and vegetation;
2. to determine the relationships among predicted and actual fuel and duff consumption and mineral soil exposure on this site; and
3. to quantify and describe changes in percent cover, height, species composition, and diversity of vegetation following burning.

2 METHODS

2.1 Study Area

This site (Opening 93H 053 0.0 50, also called 93H053-27 or Opening ID -120640000), is located in the Prince George Forest District of the Northern Interior Forest Region, southeast of Prince George at 53°30′27″ N, 121°30′27″ W, (Figure 1). The block is situated at approximately 1020 m elevation in the Sub-Boreal Spruce zone in the SBSvk or very wet cool subzone. The site has a gentle 10% slope and a southerly aspect. The combined L, F, and H horizons were 8.2 cm deep, of which 1.76 cm was litter.

The site is zonal, with pockets of slightly wetter and richer soils, and was classified as an SBSvk/01 (*Picea glauca* × *engelmannii*—*Oplopanax horridus*) site series, given the presence of *Athyrium filix-femina*, an indicator of zonal and wetter site series. It includes pockets of the SBSvk/05 (*Oplopanax horridus*—*Dryopteris expansa*) site series, which features a significant cover of *Equisetum sylvaticum*, characteristic wetter site series (DeLong 2003).

The site was clearcut in the winter of 1983 when snow cover was deep enough to prevent disturbance of the forest floor and destruction of understorey vegetation across most of the site. The site was burned on August 18, 1986 and planted in 1987 with hybrid (interior) spruce (*Picea glauca* × *engelmannii*). It was sampled for 3 years (1987, 1988, and 1989), after which herbicide was applied, and sampling was discontinued.

2.2 Data Collection

Sixteen 3.99-m radius (0.005-ha) permanent plots were established in the summer of 1987 by J. Muraro and his crew before the site was slashburned. The plots were established at intervals along two parallel lines. These plots are PB 86-4-2-008 (plots 1–16) (Figure 2).

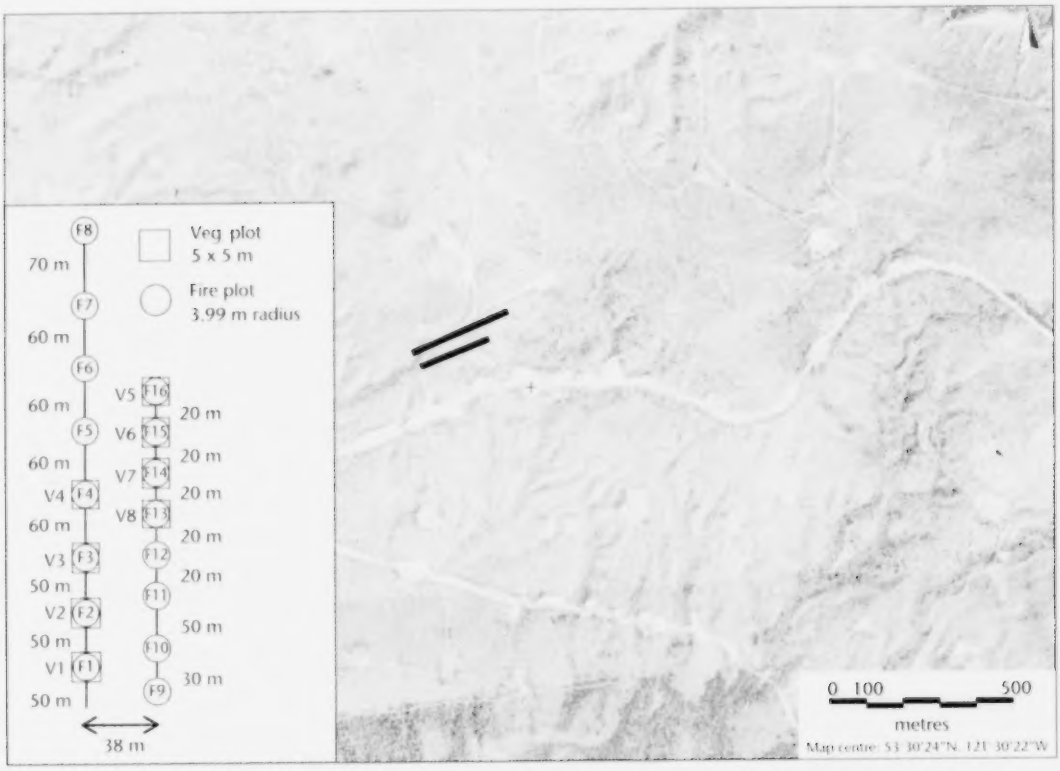

FIGURE 2 *Orthophoto of the site and layout of vegetation plots and fire effects assessment plots on the site.*

Fuels were assessed in each plot using a modification of the standard procedures described by Trowbridge et al. (1994). Four 3.99-m transects were established along the cardinal directions radiating out from each plot centre. Fuel loading and consumption were determined along these transects. The number of intersections by fuels larger than 11 mm in diameter was recorded in 11–30, 31–50, and 51–70 mm size classes along each full transect. The number of intersections of fuels in the 0–5 and 5–10 mm size classes was recorded for only the last 0.99 m of each 3.99-m transect. Diameters of fuels wider than 70 mm were recorded. Forest floor depth, depth of burn (DOB), and remaining forest floor depth were measured at 1-m intervals along the 3.99-m transects using DOB pins for a total of 16 measurement per plot (i.e., the plot centre was not measured).

Fire weather was monitored following standard procedures to calculate Canadian Forest Fire Weather codes and indices (van Wagner 1987). Four to six dominant shrub species and four to six dominant herb species in each of the 16 plots were recorded by J. Muraro and his crew in 1986 before the site

was burned. We used the vegetation data from the eight plots that we remeasured in our analysis (Table 5).

In 1987, four of the 16 fuel sampling plots were selected for long-term post-burn monitoring. A 5 × 5-m plot was overlain on each of the 3.99-m radius fuel plots. Complete vegetation data (species, presence, abundance) were collected. In 1988, four more permanent sample plots were established within the fuel plots. Vegetation was sampled in July or August of 1987, 1988, and 1989 (1, 2, and 3 years after burning). Estimated percent cover of each plant species in each plot was recorded each year. Mean height was estimated for selected herb and shrub species only. The mode of establishment, either from seed or resprouting from surviving plant parts, was recorded in 1987 for selected species.

Twenty-three planted spruce (*Picea glauca* × *engelmannii*) trees were tagged initially in 1987 and height, root collar diameter, and canopy width and breadth were measured at the time of planting. In 1988, an additional 22 trees were added to the study and measured, for a total of 45 trees. Two had died by 1989, so the values that year are based on 43 trees.

2.3 Data Analysis

Pre-burn vegetation data were compared to the appropriate units in the provincial biogeoclimatic ecosystem classification (BEC) database and the field guide for the southeastern section of the Northern Interior Forest Region (DeLong 2003) to confirm the site series classification assigned in the field.

The data collected from this site do not adhere to a formal experimental design and are descriptive rather than inferential. Graphs and descriptive statistics are used to present and assess the changes in vegetation and planted spruce over time.

Mean percent cover was calculated as the sum of the cover values for a given species, divided by the total number of sample plots, to provide a measure of abundance over the whole site.

Mean height was calculated as the sum of the heights recorded for a species, divided by the number of plots in which the species was recorded. Height was recorded for selected herbs and for all shrubs as the average of a species in the plot, taking into account the proportion of the cover of individual plants with different heights. This was done by taking several measurements where there was substantial variation, and estimating the mean. For example, if 5% of the species cover was 150 cm tall but the rest was only 90 cm tall, then the estimated height was much closer to 90 cm than to 150 cm. Since heights were recorded for all shrub species, it was possible to estimate a mean height for this lifeform using the following formula, which weights the height by cover:

$$\text{mean shrub height} = \frac{\sum_{\text{shrub species } s}^{\text{all shrub species}} (\%\ \text{cover}_s) \times (\text{mean height}_s)}{\sum_{\text{shrub species } s}^{\text{all shrub species}} \%\ \text{cover}_s}$$

Trees were not included in the calculations for shrub height. Average herb height was not calculated because not all species were measured.

Percent presence, an expression of frequency, was the proportion of plots in which each species occurred.

3.1 Fire Effects

Canadian Forest Fire Weather Index System codes and indices (Van Wagner 1987) at the time of burning were: Fine Fuel Moisture Content (FFMC) = 92, Duff Moisture Code (DMC) = 39, Drought Code (DC) = 263, and Fire Weather Index (FWI) = 34.

The pre-burn forest floor (L, F, and H horizons) depth in the 16 plots averaged 8.1 cm, of which 1.76 cm was litter and moss. The depth of burn (DOB) averaged 3.15 cm and forest floor consumption was 39.5%. Remaining duff depth averaged 5.3 cm (Table 1). Mineral soil exposure was 20.9%.

TABLE 1 *Pre-burn and post-burn depth of the forest floor, depth of burn, and percent consumption of the forest floor (n = 60 pins; mean and standard error)*

Pre-burn depth of forest floor (cm)	Post-burn depth of forest floor (cm)	Depth of burn (cm)	Consumption of forest floor (%)
8.1 (0.67)	5.3 (0.48)	3.15 (0.44)	39.5 (4.03)

Total woody fuel loading in the plots was 172.96 tonnes/ha pre-burn and total consumption was 38.2%. Fine fuel consumption was 94.2% (Table 2). The burn was classified as moderate severity.

TABLE 2 *Total woody fuel loading, total consumption, and fine fuel consumption (n = 16 plots; mean and standard error)*

Total pre-burn loading of all woody fuel (tonnes/ha)	Total consumption of all woody fuel (%)	Consumption of fine fuel (< 7 cm diameter) (%)
172.96 (16.03)	38.2 (3.5)	94.2 (2.8)

The actual forest floor consumption (39.5%) and mineral soil exposure (20.9%) were less than predicted by the Prescribed Fire Predictor (Muraro 1975) (50% and 40%, respectively). Actual total woody fuel consumption (38.2%) was slightly higher than predicted for fuels smaller than 22 cm in diameter (30%); actual fine fuel consumption (94.2%) was greater than predicted (70%) (Table 3). The Prescribed Fire Predictor (PFP) predicts consumption by size class only for pieces up to 22 cm in diameter, not total fuel consumption. These data were not broken down by size classes for pieces > 7 cm in diameter. The consumption of fuel > 22 cm in diameter was generally less than that of the smaller pieces; therefore, the consumption of these smaller pieces is expected to be even greater than that observed, and would yield an even wider discrepancy between observed and predicted PFP values, if the experimental design could support quantitative comparisons between observed and predicted total fuel consumption.

TABLE 3 *Predicted and actual duff and fuel consumption and mineral soil exposure*

Duff consumption (%)		Mineral soil exposure (%)		Total woody fuel consumption (%)		Consumption of fine fuel (< 7 cm diameter) (%)	
Pred.[a]	Actual[b]	Pred.[a]	Actual[b]	Pred.[a,c]	Actual[b]	Pred.[a,d]	Actual[b]
50	39.5	40	20.9	30	38.2	70	94.2

a Predicted based on Prescribed Fire Predictor (Muraro 1975)
b Actual consumption of woody fuel are estimates based on 16 fuel assessment plots
c Predicted consumption of woody fuel < 22 cm in diameter
d Predicted consumption of woody fuel < 7 cm in diameter

3.2 Vegetation

The number of shrub and herb species increased over time. This reflects improvements in the ability to identify species (as they grew larger and flowered) as well as actual increases in species numbers. Pre-burn data are incomplete and are based on the list of four to six dominant shrubs and herbs noted as present during the pre-burn fuel sampling and species observed to have resprouted in 1987, immediately post-burn. This number should be considered the minimum number of pre-burn taxa (Table 4).

TABLE 4 *Number of taxa by lifeform in each year*

	Lifeform			
Year	Trees	Shrubs	Herbs	Total
Pre-burn 1986[a]	≥ 3	≥ 11	≥ 11	≥ 25
1987	1	9	16	26
1988	2	10	21	33
1989	2	8	28	38

a Based on enumeration of the four to six pre-burn dominant shrubs and herbs and post-burn presence of resprouting plants; this is the minimum number of species present pre-burn

Most of the shrub species observed in the plots prior to burning survived the fire and gradually increased in percent cover, height, and presence across plots (Table 5; Figures 3, 4, and 5). The increase in height was more pronounced than the increase in percent cover, which tended to be quite gradual. *Rubus parviflorus* resprouted after burning and was the dominant shrub for the first 3 years after burning; its cover declined somewhat as *Epilobium angustifolium* became established on the site. One year after the fire, *Oplopanax horridus*, a diagnostic species of the site series, was not observed in a number of plots in which it was observed prior to burning. It gradually increased in presence, cover, and height over time. *Spiraea betulifolia*, *Vaccinium membranaceum*, and *Sambucus racemosa* increased in frequency. *Lonicera involucrata* and *Cornus stolonifera* were some of the few shrubs that declined in presence after the fire. *Sambucus racemosa*, *Rubus idaeus*, and *Ribes laxiflorum* resprouted and established from buried seeds. Many of the germinants of these species died after the first year, leading to the decline in presence observed in some plots.

TABLE 5 *Mean cover and percent presence of vegetation pre-burn and 1, 2, 3, and 5 years after burning on the Haggen Creek site*

	Cover (%)					Presence (%)				
	Pre-burn	Post-burn				Pre-burn	Post-burn			
Species	1986[b] 8[d]	1987 4	1988 8	1989 8	1991 8	1986[c] 8	1987 4	1988 8	1989 8	1991 8
Trees										
Acer glabrum var. *douglasii*	P		0.3	0.3	0.3	12.5		12.5	12.5	12.5
Picea engelmannii × *glauca*		+[a]	+[a]	+[a]	+[a]		100	100	100	100
Prunus virginiana										
Shrubs										
Cornus stolonifera	P		0.1		0.3	25		12.5		12.5
Lonicera involucrata	P		0.1			37.5		12.5		
Oplopanax horridus	P	0.03	0.3	0.4	0.5	75	25	37.5	62.5	50
Ribes lacustre	P	0.3			0.03	*	25			12.5
Ribes laxiflorum	P	0.4	0.3	0.2	0.5	*	50	37.5	25	62.5
Rosa acicularis	P	2.5	1.3	1.0	2.9	25	25	25	25	25
Rubus idaeus	P	3.3	3.1	3.4	6.8	50	100	75	87.5	100
Rubus parviflorus	P	28.8	13.7	13.9	8.4	75	100	100	100	87.5
Sambucus racemosa	P	1.8	1.1	0.7	0.3	25	100	25	25	37.5
Spiraea betulifolia	P	1.3	2.5	4.6	5.5	12.5	25	62.5	62.5	62.5
Vaccinium membranaceum	P	0.03	0.1	0.2	0.3	12.5	25	50	37.5	62.5
Herbs										
Actaea rubra			0.1	0.1	0.03			12.5	12.5	12.5
Agoseris sp.				0.1	0.1	*****			12.5	12.5
Anaphalis margaritacea				0.1	0.6				12.5	87.5
Aralia nudicaulis			0.9	0.5	0.4			50	37.5	37.5
Arnica cordifolia							25			
Athyrium filix-femina	P	1.8	2.6	1.1	0.2	100	50	50	50	25
Cerastium sp.			0.1	0.1					12.5	12.5
Cinna latifolia	P	0.5	0.5	0.7	7.9	***** 50	50	50	62.5	62.5
Cirsium sp.				0.1			*			12.5
Clintonia uniflora	P	0.4	1.8	0.9	0.6	12.5	75	87.5	87.5	87.5
Cornus canadensis	P	1	3.4	6.9	35.6	62.5	75	87.5	87.5	87.5
Crepis sp.				0.5						50
Dryopteris expansa			+	0.1			25		25	
Epilobium angustifolium	P	27.8	31.9	35.3	7.2	75	100	100	100	100
Epilobium ciliatum		0.2	0.2	0.6			25	37.5	37.5	25
Equisetum arvense	P		1.4	0.5	7.6	***		37.5	37.5	62.5
Equisetum sylvaticum	P	20.3	11.9	9.4	15.8	***	75	50	37.5	37.5
Galium triflorum			0.1	0.1	0.2			37.5	25	37.5
Gymnocarpium dryopteris	P	1.6	2.4	1.7	0.1		75	100	100	12.5
Hieracium albiflorum				0.1	0.4				12.5	37.5
Hieracium sp.			0.1	0.2	1.4		25	37.5	37.5	50
Maianthemum racemosum	P		0.3	0.1		****	25	12.5	12.5	
Maianthemum stellatum	P		3.2	5.1	11.8	****	50	75	100	87.5
Petasites palmatus				0.01						12.5
Poa sp.			0.1	0.9		*****			25	25

TABLE 5 *Continued*

	Cover (%)					Presence (%)				
	Pre-burn	Post-burn				Pre-burn	Post-burn			
Species	1986[b] 8[d]	1987 4	1988 8	1989 8	1991 8	1986 8	1987 4	1988 8	1989 8	1991 8
Poaceae #2[e]				0.1	0.1	*****			12.5	12.5
Streptopus amplexifolius			0.2	0.2	0.0			37.5	25	12.5
Streptopus roseus			1.9	2.6	3.0		75 *	75	100	87.5
Taraxacum sp.			0.1	0.1	0.3			12.5	12.5	75
Tiarella trifoliata ssp. *trifoliata*	P		0.8	0.6	0.4	**	50	87.5	87.5	75
Tiarella trifoliata ssp. *unifoliata*	P					**	25			
Veratrum viride						37.5				
Viola sp.	P		0.01					12.5		
unknown herb				0.6					25	
Bryophytes										
Brachythecium sp.			0.4					37.5		
Marchantia polycephalum			0.0					12.5		
Polytrichum sp.			0.1	0.1	0.3			12.5	12.5	37.5

a + = presence in plots post-burn is assumed since the whole site was planted at standard spacing

b P = presence pre-burn was noted by fire effects assessors in plots, cover was not recorded.

c this information was collected by the fire effects assessors

* = "*Ribes*" were noted in 12.5% of the plots pre-burn, "gooseberry" was noted in 37.5% of the plots pre-burn;

** = "Foamflower" was noted in 62.5 % of plots pre-burn;

*** = "Horsetail" was noted in 50% of plots pre-burn;

**** = "Solomon's-seal" or *Smilacina* sp. [now *Maianthemum*] was noted in 12.5% of plots pre-burn, "star-flowered Solomon's-seal" or *Smilacina stellata* [now *Maianthemum stellatum*] was noted outside of plots;

***** = "Grass" was noted in 50% of the plots pre-burn.

d Number of plots

e This is a member of the Poaceae family that could not be identified beyond the family level; the numbers refer to the specimen number

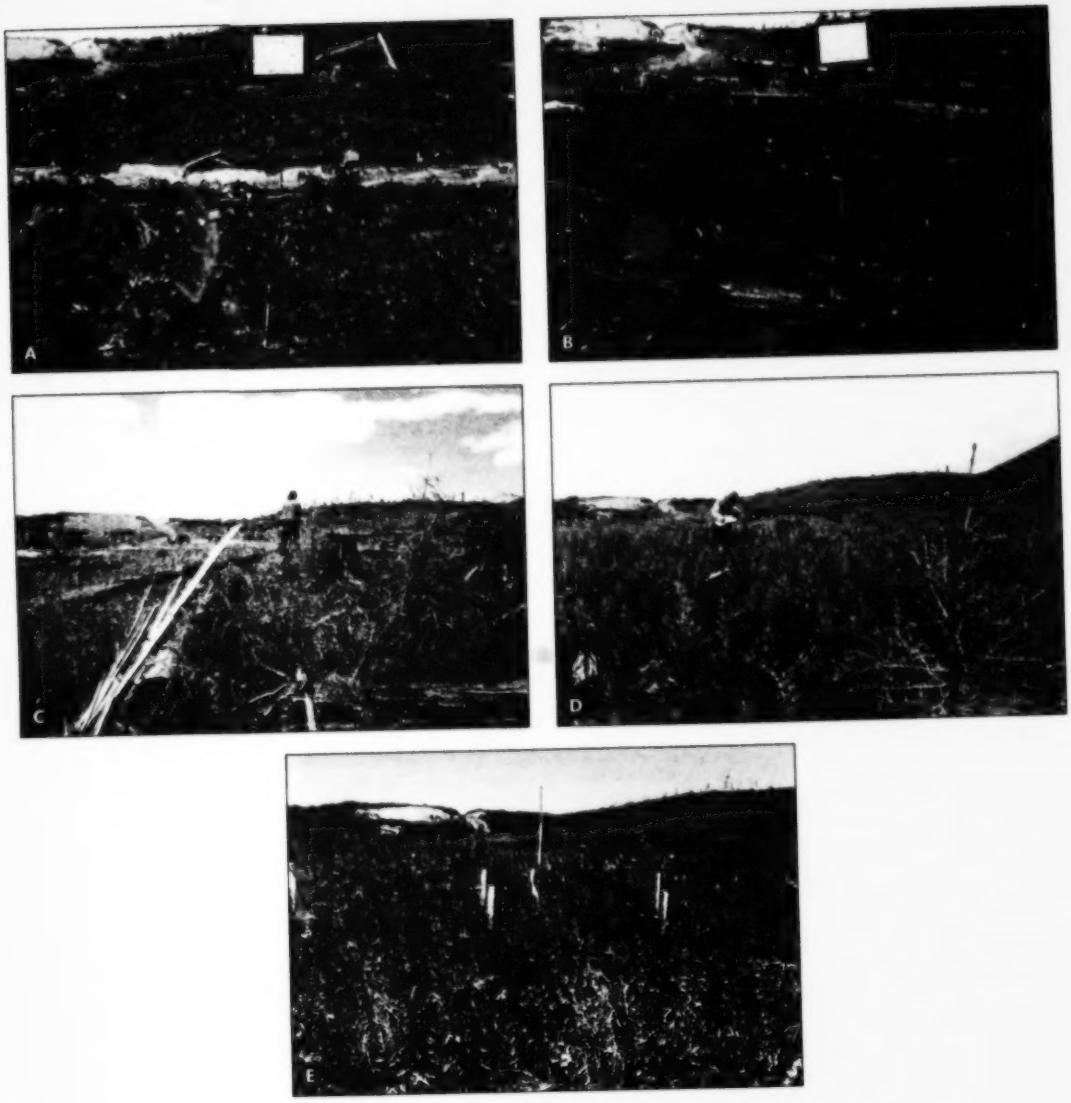

FIGURE 3 *Photos of the site (A) pre-burn, (B) immediately after burning, (C) 1 year after burning, (D) 2 years after burning, and (E) 3 years after burning.*

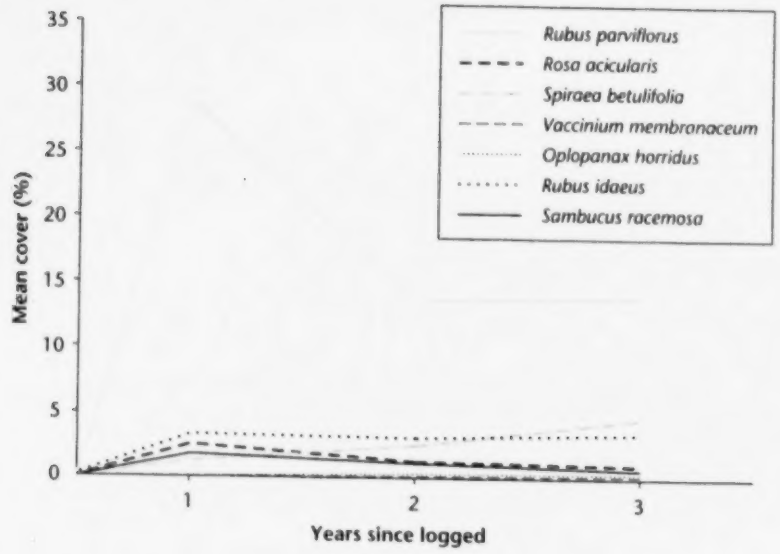

FIGURE 4 *Estimated mean percent cover of selected shrubs over time.*

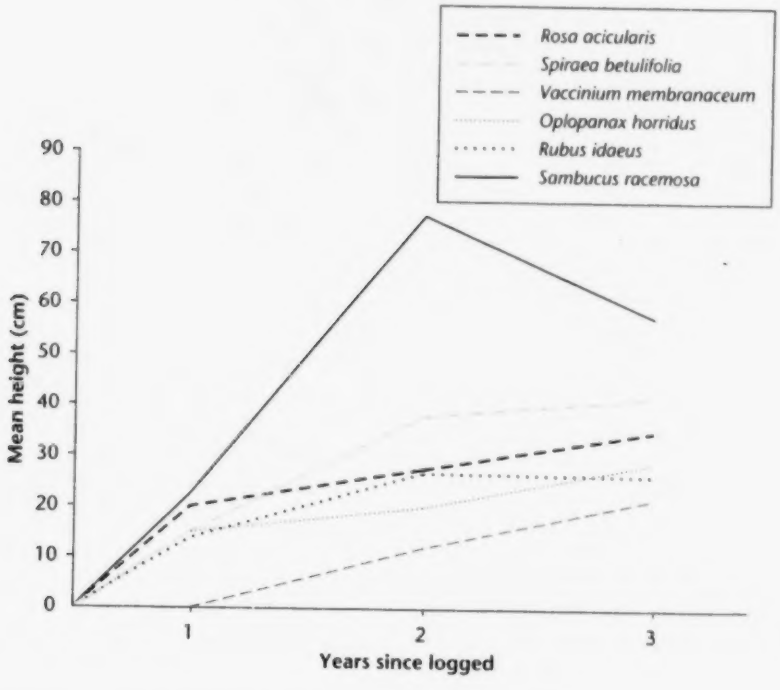

FIGURE 5 *Estimated mean height of selected shrubs over time.*

Epilobium angustifolium was the dominant herb on the site. Its cover increased over the 3 years of the study (Figure 6). Most other herb species slowly increased in cover, except for *Equisetum sylvaticum*, a diagnostic species in the SBSvk/05 site series, which was quite abundant initially and then declined somewhat. Height was assessed only for a few dominant species; herb height did not change much over time (Figure 7).

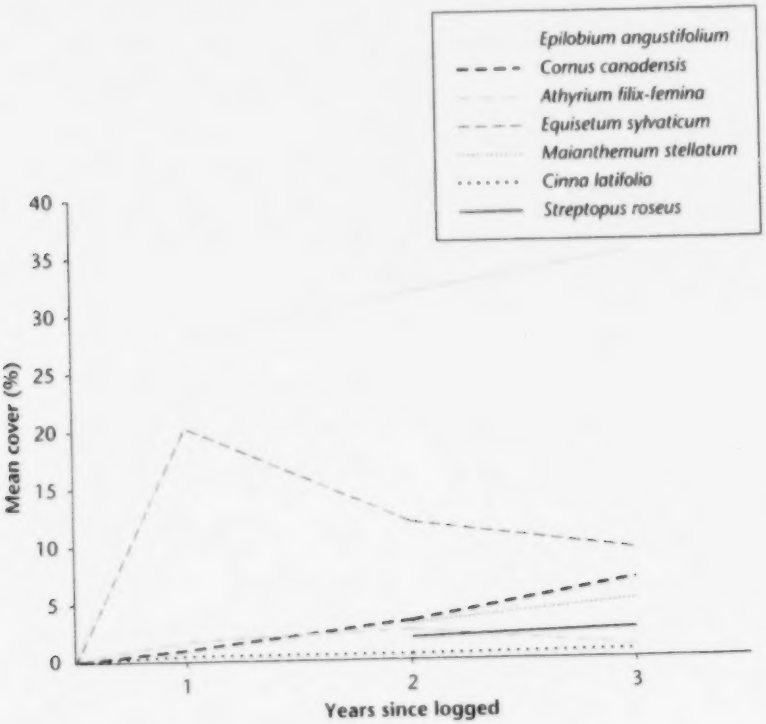

FIGURE 6 *Estimated mean percent cover of selected herbs over time.*

The increase in herb richness was due to re-establishment of species typical of forested successional stages, the establishment of new species from buried seeds (i.e., *Epilobium ciliatum*), and the establishment of new species typical of open habitat from wind-dispersed seeds (e.g., *Epilobium angustifolium*, *Hieracium* sp., *Anaphalis margaritacea*, *Crepis* sp., and *Taraxacum* sp.). *E. ciliatum* is an ephemeral species with long-term seed dormancy. *Veratrum viride* was reportedly present prior to burning, but was never observed after.

Species that are indicators of wetter site series in the SBSvk subzone (e.g., *Veratrum viride*, *Equisetum sylvaticum*, and *Athyrium filix-femina*) declined during the first 3 years after burning. This suggests that burning of some of the forest floor led to drier site conditions post-harvest.

Planted hybrid spruce trees increased rapidly in percent cover, height, and frequency. By 1989, the coniferous tree layer was about 45 cm tall.

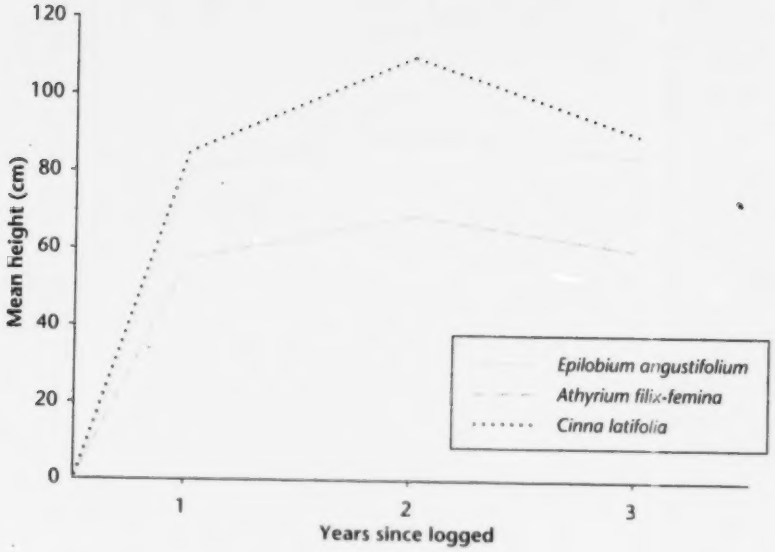

FIGURE 7 *Estimated mean height of selected herbs over time.*

4 DISCUSSION

This was a moderately severe fire, conducted under relatively dry conditions. Relative to other sites studied in the SBS and ESSF (Hamilton and Peterson 2003, 2006; Hamilton and Hauessler 2005, 2006; Hamilton 2006a, 2006b, 2006c), this fire yielded one of the higher FWI values (34), a high DOB (2.8 cm), and moderate total fuel consumption (37%).

It was notable that many of the original species on this site were sparse or absent the year after burning. This was true of indicator species such as *Oplopanax horridus,* which was recorded in 75% of the 16 fuel sample plots prior to burning, but in only 25% of the vegetation sample plots immediately post-burn, at very low cover. These results suggest that changes in indicator species abundance occur after significant disturbances, and this should be kept in mind when classifying sites when they are in early seral stages.

One of the distinguishing characteristics of this site was the preponderance of *Rubus parviflorus,* which proliferated from buried seeds and resprouting, and which had close to 30% cover the year after burning. Most other comparable sites had more uniform species cover distributions. *R. parviflorus* was widely distributed on the site prior to burning (present in 75% of the fuel sampling plots) and this was likely a significant factor in its post-fire domination of the site. It may also have been particularly favoured by other factors influencing this site. For instance, although trees were harvested from the site in the winter of 1983, the site was not burned until 1986, providing a favourable environment for species such as *R. parviflorus* that thrive in sunny, open site conditions.

Abstract

Fire effects, understorey vegetation, and planted tree seedling responses to burning were monitored for 10 years after slashburning. Changes in floristic composition and structure (percent cover and height) were tracked. A standard fire weather station was used to determine fire weather codes and indices and to predict forest floor moisture content. Woody fuel loading and consumption and burn severity were determined using a line-intercept approach in standard fire effects assessment triangles.

The burn was of moderate severity, with little mineral soil exposure. Forest floor consumption and mineral soil exposure were less than predicted by the Prescribed Fire Predictor, and woody fuel consumption was greater than predicted.

After the site was logged and burned, the ground-level vegetation structure shifted from a community dominated by bryophytes and small herbs to a young conifer forest with mosses, taller herbs, and shrubs. After 10 years, herb cover was about 40% and shrub cover was about 30%. Some of the original forest species were lost in some plots. Many new species established from the seed bank and sources outside of the plot.

The resilience of the native vascular species demonstrates the fire-adapted nature of this ecosystem. Shrubs typical of wetter sites were not as well adapted to burning as species more typical of drier forests, which would be expected given the more frequent fires typical of the latter.

1.1 Background and Rationale

Development of sustainable forest management practices requires an understanding of the short- and long-term impacts of harvesting and site preparation on all forest vegetation. Clearcutting and slashburning have been widely practised in British Columbia, but little is known about subsequent patterns of vegetation development or how management activities, particularly slashburn severity, influence these patterns. The strong positive response to FRDA Report 018 (Hamilton and Yearsley 1988) indicates that predictive models of forest vegetation succession are essential for developing management prescriptions that meet such integrated resource use objectives as forest regeneration, providing wildlife habitat, and maintaining biodiversity. The information will also contribute to the development of a seral classification within the biogeoclimatic ecosystem classification (BEC) system.

Successional information can be gathered in two ways. The chronosequence method involves sampling many sites of different ages (years since disturbance). The second method involves repeated measurement at regular intervals of vegetation in permanent plots. The advantage of the chronosequence method is that it is possible to reconstruct a successional sequence based on a single year's data collection. This was the approach we took with the FRDA 018 project. The difficulty is finding and identifying sites that are ecologically similar and that have undergone the same type and severity of disturbance (e.g., harvesting and site preparation). With the permanent plot approach it is possible to select ecologically similar sites and measure the impact of the chosen disturbance, but it takes many years to collect enough data to determine successional patterns.

This site is one of several in the Sub-Boreal Spruce (SBS) zone where vegetation is being monitored after clearcutting and slashburning. The study is among very few in British Columbia to record slashburning severity and collect several years of post-burn data on all vegetation species in permanent plots. Although similar data are being collected on several sites in the Northern Interior Forest Region, and a number of other chronosequence and combined studies have been done, very little of this information has been published. Results from our sites will be combined to form the basis of a preliminary report on early forest succession in the SBS zone, and will be compared to the patterns derived from a set of similar sites that we are monitoring in the ESSF zone.

1.2 Objectives

The objectives of this study are:

1. to quantify and describe changes in percent cover, height, species composition, and diversity of vegetation over time; and
2. to assess the interactions between burn severity (depth of burn) and vegetation development.

2.1 Study Area

This site (Cutting Permit 19194, Opening number 936 079-16, BC 84019) is located in the Prince George Forest District of the Northern Interior Forest Region southeast of Prince George (Figure 1). The block is situated at approximately 850 m elevation in the Sub-Boreal Spruce zone in the SBSmk1 or Mossvale variant of the moist cool subzone. The site is at 53°44′56″ N, 122°20′52″ W. Before logging, the site supported the vegetation association typical of the SBSmk1/01 (*Picea glauca* × *engelmannii*—*Vaccinium membranaceum*—*Viburnum edule*) site series. Plots are located on a slight (approximately 10%) northeast-facing slope.

The site was clearcut in the winter of 1985–86 when snow cover was deep enough to prevent disturbance of the forest floor and destruction of understorey vegetation across most of the site. The block was burned on September 9, 1986 and planted in 1987 with both lodgepole pine (*Pinus contorta* var. *latifolia*) and Engelmann spruce (*Picea engelmannii*).

2.2 Data Collection

Data on fire effects and vegetation response after burning were collected, using a combination of fire effects assessment triangles and permanent vegetation plots. Sampling was initiated in 1987 prior to burning and continued for 10 years. Three operational fire effects assessment triangles were installed on the site following standard procedures (Trowbridge et al. 1994)(Figure 8). Six permanent plots were established at the mid-point of each side of the two of the triangles in the summer of 1987 after slashburning. Fire weather was monitored following standard procedures, and Canadian Forest Fire Weather codes and indices (Van Wagner 1987) were also calculated.

2.2.1 Fire effects Three fire effects assessment triangles (30 m per triangle side for a total of 270 m of line-intersect sampling) were installed on the site by J. Muraro and his crew following standard methods (Trowbridge et al. 1986). Depth of burn (DOB) pins were installed at 5-m intervals along all three sides of the triangles, except at the vertices (30 pins/triangle or 90 pins in total).

The DOB and remaining duff depth was determined at each pin after burning. Woody fuel loading was determined prior to burning, and consumption was determined by resampling the transects after the fire.

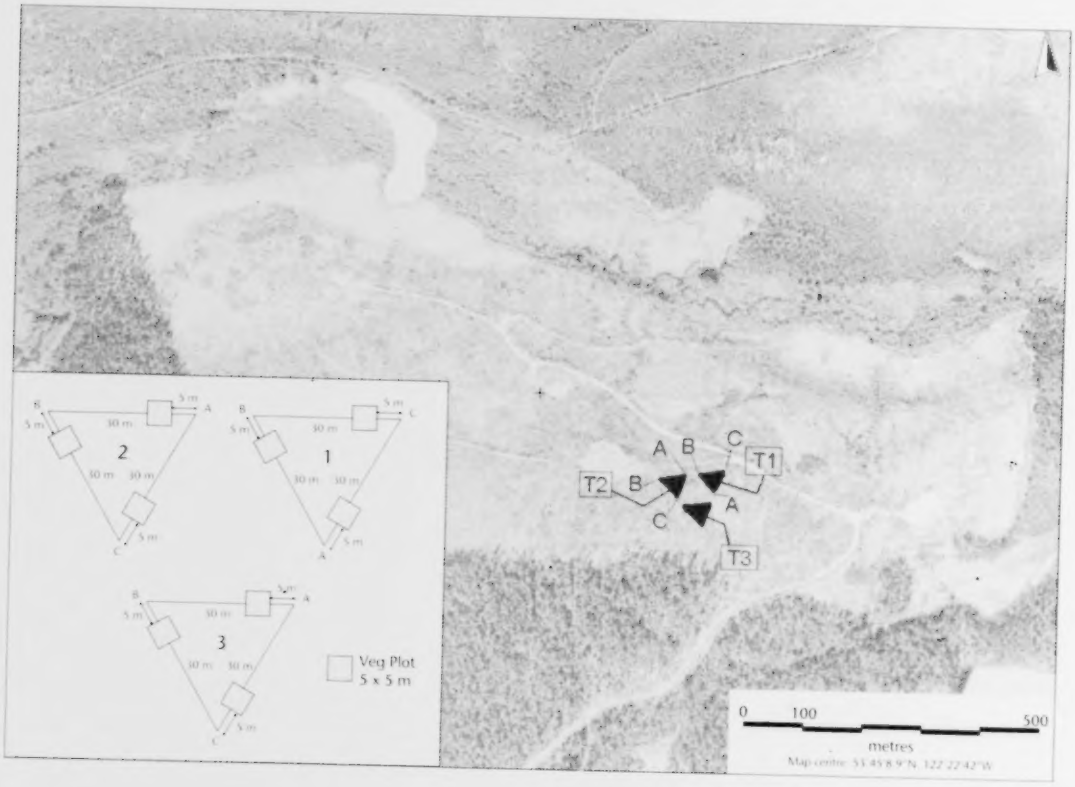

FIGURE 8 *Orthophoto of the site and layout of fire effects assessment triangles on the site (layout of vegetation plots inset).*

2.2.2 Vegetation Six 5 m × 5-m permanent plots were established in the summer of 1987, a year after the site was slashburned. These plots were superimposed on two of the three fire effects assessment triangles (Figure 8).

The presence of the key plant species in two triangles and the cover of key species in one triangle were recorded just prior to burning by J. Muraro and his crew. We collected complete vegetation data from the plots in July or August of 1987, 1988, 1989, 1991, and 1996 (1, 2, 3, and 5 years after burning; Figure 9). Estimated percent cover of each plant species in each plot was recorded each year. Mean height was measured for selected herb and shrub species only. The mode of establishment, either from seed or resprouting from surviving plant parts, was recorded in 1987 for selected species. All vascular plant species were recorded, but few non-vascular plants were recorded until 1996, because data collectors were not sufficiently trained to recognize rarer species. In 1996, non-vascular plants were collected and identified by an expert, F. Boas. Because of the inconsistency in species identification in different years, changes in diversity of non-vascular species cannot be predicted with confidence from these data.

FIGURE 9 *Photos of the site (A) pre-burn, (B) immediately after burning, (C) 1 year after burning, (D) 2 years after burning, (E) 3 years after burning, and (F) 5 years after burning.*

Percent cover is defined as an estimate of the actual area covered by projecting the leaves of the species onto the ground, not the area defined by the outline of the plants. Percent cover for all species combined (total) was also recorded in the field, but total cover for herbs and shrubs was never recorded. Non-vascular plants are included in the total percent cover estimates.

Height was recorded for selected herbs and all shrubs and, in some years, all species combined (total). Only vascular plants are included in the total height values since non-vascular plants contribute little to the above-ground structure of forest vegetation. Height was considered the average height of a species in the plot, taking into account the proportion of the cover of individual plants with different heights. This was done by taking several measurements where there was substantial variation, and estimating the mean. For example, if 5% of the species cover was 150 cm tall but the rest was only 90 cm tall, then the estimated height was much closer to 90 cm than to 150 cm.

Since heights were recorded for all shrub species, it was possible to estimate a mean height for shrubs using the following formula, which weights the height by cover:

$$\text{mean shrub height} = \frac{\sum_{\text{shrub species } s}^{\text{all shrub species}} (\%\ \text{cover}_s) \times (\text{mean height}_s)}{\sum_{\text{shrub species } s}^{\text{all shrub species}} \%\ \text{cover}_s}$$

Trees in the shrub layer were not included in the calculations for shrub height. Average herb height could not be calculated because not all species were measured.

No trees were tagged and measured on this site, but the cover and mean height were recorded for both conifer and hardwood species. Lodgepole pine and spruce were both planted on the site.

2.3 Data Analysis

Pre-burn vegetation data were compared to the appropriate units in the provincial biogeoclimatic ecosystem classification (BEC) database and a draft version of the field guide update for the Northern Interior Forest Region (DeLong 2003) to confirm the site series classification.

The data collected from this site are descriptive in nature and no formal experimental design was employed. Therefore graphs and descriptive statistics, rather than formal analyses, are used to present and assess the changes in vegetation and planted spruce over time.

Mean percent cover was calculated as the sum of the cover values for a given species, divided by the total number of sample plots to provide a measure of abundance over the whole site. Mean height was calculated as the sum of the heights recorded for a species, divided by the number of plots in which the species was recorded. Percent presence, an expression of frequency, is the percentage of plots in which each species occurred.

The weighted averages of the fire effects data collected from triangles and plots (i.e., pre- and post-burn fuel loading and consumption, pre- and post-burn duff depth, depth of burn, and percent consumption) were determined to calculate site averages.

3.1 Fire Effects

Canadian Forest Fire Weather Index System codes and indices (Van Wagner 1987) at the time of burning were: Fine Fuel Moisture Content (FFMC) = 89, Duff Moisture Code (DMC) = 20, and Drought Code (DC) = 410.

The pre-burn forest floor depth in the three triangles averaged 12.5 cm, of which 2.9 cm was comprised of the litter layer. The depth of burn (DOB) averaged 3.8 cm and forest floor consumption was 30.2% (Table 6). The moss layer was quite thick on this site and the DOB reflects the consumption of this layer, other litter, and about 0.8 cm of the underlying F and H horizons.

TABLE 6 *Pre-burn litter depth, and post-burn forest floor depth, depth of burn, and percent consumption of the forest floor (mean and standard error)*

Source	Pre-burn litter depth (cm)	Pre-burn depth of forest floor (cm)	Post-burn depth of forest floor (cm)	Depth of burn (cm)	Consumption of forest floor (%)
Site total (n = 90 DOB pins)	2.9 (0.25)	12.5 (0.64)	8.7 (0.22)	3.8 (0.43)	30.2 (1.8)

Total woody fuel loading in the triangles was 130.7 tonnes/ha pre-burn and total consumption was 47.4%. Fine fuel consumption was 94.2% (Table 7). This was a somewhat patchy, moderate-severity burn.

TABLE 7 *Total woody fuel loading, total consumption, and fine fuel consumption (mean and standard error)*

Source	Total pre-burn loading of all woody fuel (tonnes/ha)	Total consumption of all woody fuel (%)	Consumption of fine fuel (< 7 cm diameter) (%)
Site total (270 m of transect)	130.7 (9.5)	47.4 (2.58)	94.2 (1.3)

Actual forest floor consumption and mineral soil exposure were less than predicted by the Prescribed Fire Predictor (PFP)(Muraro 1975). Actual total woody fuel consumption was slightly greater than predicted for fuels smaller than 22 cm in diameter (Table 8). The PFP predicts fuel consumption by size class for pieces up to 22 cm in diameter, but not total fuel consumption. The collected data on consumption was not broken down by size classes for pieces > 7 cm in diameter. The consumption of fuel > 22 cm in diameter was generally less than that of the smaller pieces, which are expected to have higher consumption rates than those observed (47.2%), and the discrepancy between observed and PFP predicted values would have been even wider if this study was designed to compare observed and predicted total fuel consumption.

TABLE 8 *Predicted and actual duff and fuel consumption and mineral soil exposure*

Duff consumption (%)		Mineral soil exposure (%)		Total woody fuel consumption (%)		Consumption of fine fuel (< 7 cm diameter) (%)	
Pred.[a]	Actual[b]	Pred.[a]	Actual[b]	Pred.[a,c]	Actual[b]	Pred.[d]	Actual[b]
45	30.2	30	10.6 (7.3 pre-burn)	30	47.4	70	94.2

a Predicted based on Prescribed Fire Predictor (Muraro 1975)
b Actual consumption of woody fuel and duff and mineral soil exposure based on three fuel triangle measurements
c Predicted consumption of woody fuel < 22 cm in diameter
d Predicted consumption of woody fuel < 7 cm in diameter

3.2 Vegetation

The number of shrub species increased and herb species diversity doubled. These numbers reflect improvements in the ability to identify species (as they grew larger and flowered) as well as true increases in species numbers. The increase in diversity of non-vascular plants in 1996 reflects the expert identifications done that year (Table 9).

TABLE 9 *Number of taxa by lifeform in each year*

	Lifeform				
Year	Trees	Shrubs	Herbs[a]	Non-vascular plants[b]	Total
1987	2	10	17	0	29
1988	3	8	22	1	34
1989	4	11	22	2	39
1991	3	13	22	1	39
1996	5	14	36	25	80
Total taxa[c]	5	14	39	26	841

a Includes graminoids
b Includes mosses, liverworts, and lichens
c Total number of taxa recorded over all years and lifeforms

Planted lodgepole pine trees and invading hardwoods (trembling aspen [*Populus tremuloides*] and paper birch [*Betula papyrifera*]) increased in percent cover, height, and frequency. By year 10 they were the dominant vegetation on the site (Figures 10 and 11). Paper birch seeded into the site and trembling aspen re-established by suckering.

All of the shrub species present prior to burning (*Rubus parviflorus, Lonicera involucrata, Spiraea betulifolia, Viburnum edule, Ribes lacustre, Sorbus scopulina, Vaccinium membranaceum,* and *Oplopanax horridus*) resprouted from below-ground meristems after the site was burned. *Rubus idaeus* and *Sambucus racemosa* established from buried seeds, with *R. idaeus* appearing in all post-burn plots. *Spiraea betulifolia* appears to have established from seed in at least one plot. Some shrub species known to establish from buried

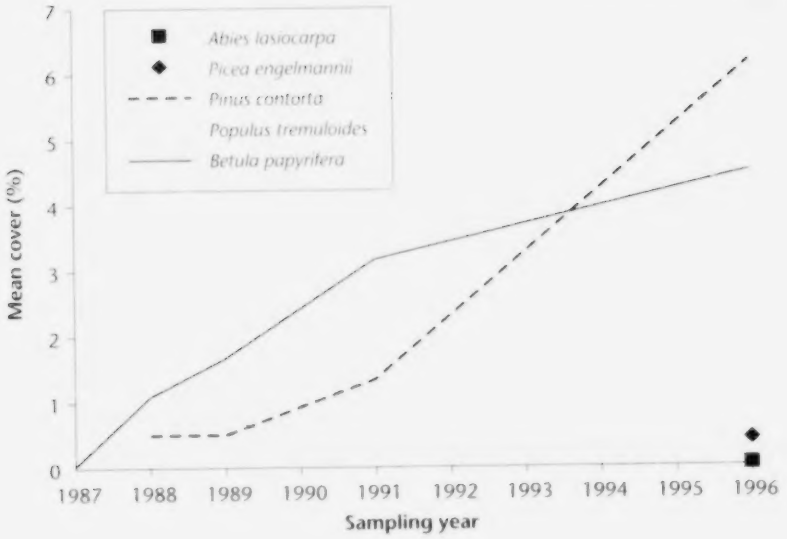

FIGURE 10 *Estimated mean percent cover of selected trees over time.*

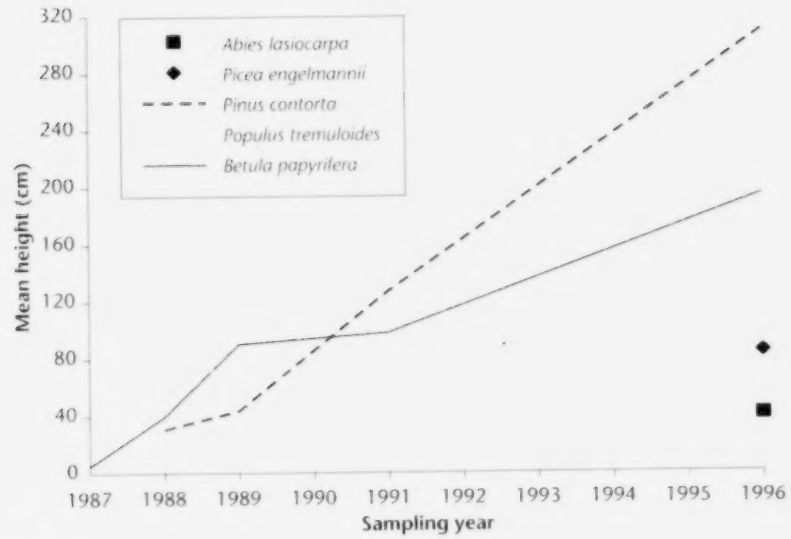

FIGURE 11 *Estimated mean height of selected trees over time.*

seeds (*Ribes laxiflorum* and *Prunus pensylvanica*) were not recorded the first year post-burn; this may reflect difficulty in identifying the young germinants of these species rather than delayed germination. *Salix* sp., *Alnus viridis* ssp. *sinuata*, and *Amelanchier alnifolia* appear to have seeded in over time as the conifers and hardwood trees grew to dominate the site. The shrub layer was initially dominated by *Rubus parviflorus*, with other shrubs increasing in prominence over time. All shrubs except *Spiraea betulifolia* decreased in percent cover over time, and all except *Lonicera involucrata* also decreased in modal height over time (Figures 12 and 13).

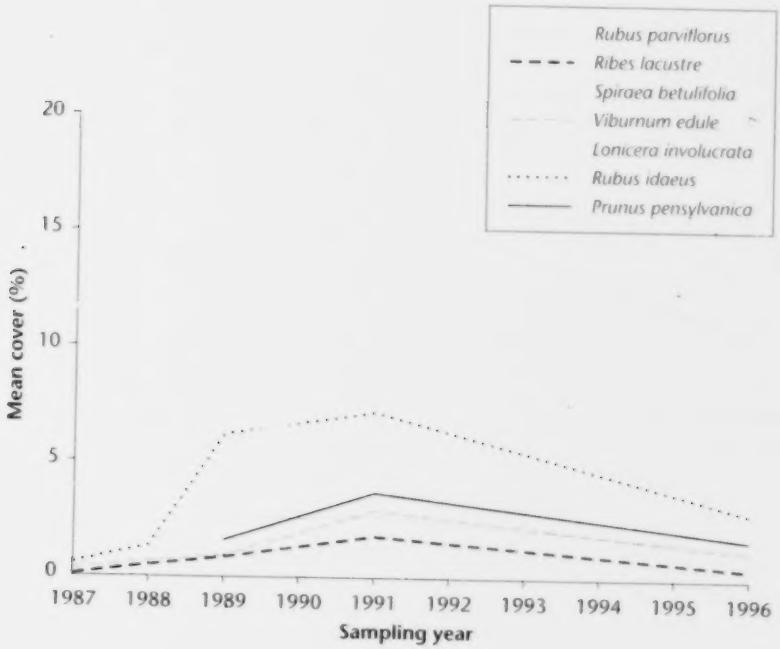

FIGURE 12 *Estimated mean percent cover of selected shrubs over time.*

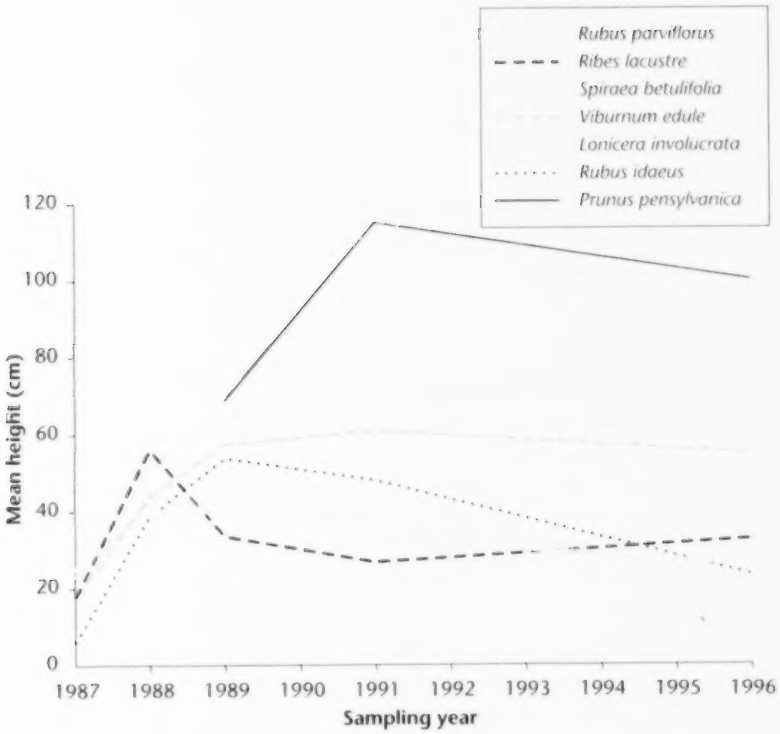

FIGURE 13 *Estimated mean height of selected shrubs over time.*

The increase in herb numbers was due in part to the establishment of genera adapted to open habitat with wind-dispersed seeds, such as *Hieracium*, *Anaphalis*, and *Taraxacum*, and in part to re-establishment of original species more typical of the forested habitat such as *Pyrola asarafolia*, *Linnaea borealis*, *Orthilia secunda*, *Tiarella trifoliata*, and *Lycopodium complanatum*, which are mycotrophic and/or sensitive to disturbance (Table 10). Three herb species were present in the first few years, but gone by the fifth: *Geranium bicknellii*, *Epilobium ciliatum*, and *Corydalis sempervirens*. These species are known to be ephemeral in habit with long-term seed dormancy. *G. bicknellii* established in all the plots and was quite abundant the first year after burning, indicating an extensive seed bank on the site. It was absent from most plots by year 5, decreasing as other competing vegetation increased. A species of *Carex* (possibly *C. mertensii*, which was identified on the site in year 10) established from buried seeds in all plots. Its cover declined over time, almost disappearing by year 10. *Calamagrostis canadensis* increased in cover over time, and flowered prolifically the first year after burning.

Epilobium angustifolium, *Cornus canadensis*, *Rubus pubescens*, and *Carex* sp. dominated the herb layer for the first few years (Figures 14 and 15). By year 10, *Epilobium angustifolium* and *Carex* sp. were in decline; *Cornus canadensis* and *Rubus pubescens* continued to increase in abundance. Most herbs decreased in mean height over time and maintained a relatively low percent cover (Figure 16).

TABLE 10 *Mean cover, percent presence, and mode of establishment of species pre-burn and 1, 2, 3, 5, and 10 years after burning on the Francis Lake site*

	Cover (%)						Presence (%) and mode of establishment							
	Pre-burn		Post-burn				Pre-burn		Post-burn					
Species	1986[a] tri.	1987 plots	1988 plots	1989 plots	1991 plots	1996 plots	1986[b] tri.	1986[c] plots	1987 plots	1987[d] MOE	1988 plots	1989 plots	1991 plots	1996 plots
Trees														
Abies lasiocarpa						0.03								33
Betula papyrifera		0.03	1.08	1.67	3.17	4.5			33	S	83	83	83	83
Picea glauca × *engelmannii*						0.42	50							67
Pinus contorta var. *latifolia*			0.5	0.5	1.33	6.17					50	50	50	100
Populus tremuloides		0.18	0.17	0.08	0.08	0.5	50		50	R	17	17	17	67
Shrubs														
Alnus viridis ssp. *sinuata*				0.17		0.08						17		17
Amelanchier alnifolia						0.17								17?
Lonicera involucrata	p	0.42	1.67	2.5	2.67	1.33	P	67	67	R	67	67	67	67
Oplopanax horridus	p	0.02			0.5	0.08	P	17	17	R			17	17
Prunus pensylvanica				1.58	3.67	1.7						67	67	83
Ribes lacustre	<1	0.1	0.5	0.85	1.78	0.45	100	17	33	R	17	33	50	67
Ribes laxiflorum			0.42s	0.5	0.25	0.28			1	Sb	50Sb	50	50	67
Rubus idaeus		0.58	1.33	6.17	7.17	2.85			100	Sb	67	67	83	100
Rubus parviflorus	p	11.7	6.5	12.5	16.2	10.5	P	83	83	R	83	100	100	100
Salix sp.				0.08	0.17	0.83						17	17	33
Sambucus racemosa		0.02	0.33	0.67	0.83	0.02			17	Sb	33	50	67	17
Sorbus scopulina	<1	0.08		0.17	0.33	0.25	100	17	17	R		17	17	33
Spiraea betulifolia	<1	3.92	4.67	6	7.5	7.58	100	83	83	R/S	83	83	83	83
Vaccinium membranaceum	<1	0.2			0.88	0.32	100	67	67	R			50	83
Viburnum edule	2	0.33	0.67	0.92	2.92	1.17	100	33	50	R	33	67	83	67
Herbs														
Anaphalis margaritacea					0.03	0.02							17	17
Aralia nudicaulis	p	0.75	2	3.83	3.67	1.2	P	17	83	R/S	100	100	100	100
Arnica cordifolia	<1	1.75	2.5	2	2.67	0.25	50		50	Sb	33	33	33	33
Cimtonia uniflora		0.28	1.58	0.92	0.92	0.93			83		100	100	100	100
Cornus canadensis	10	2.17	4.33	8	12.5	15	100	M	83	R	100	100	100	100
Corydalis sempervirens		2.75	1.83	0.02					83	Sb	67	17		
Epilobium angustifolium		1.25	5.83	11.2	14.3	9.17			83	Sb	83	100	100	100
Epilobium ciliatum			0.17	0.1					1s	Sb	17Sb	33		
Equisetum sylvaticum		0.02	0.5	0.17	0.08	0.03			17		17	17	17	33
Geranium bicknellii		21.7	1.67	0.12		0.03			100	Sb	100	50		33*
Gymnocarpium dryopteris	1	0.27	0.33	0.25	1.58	1.02	50		67		33	33	83	83
Hieracium aurantiacum						0.02								17
Hieracium gracile			0.33	0.17	0.5	0.43					17	17	17	100
Hieracium sp.						0.02								17
Linnaea borealis	<1			0.33	0.5	0.5	100					17	17	17
Luzula parviflora						0.02								17
Lycopodium complanatum	15					0.02	100							17

	Cover (%)						Presence (%) and mode of establishment							
	Pre-burn		Post-burn				Pre-burn				Post-burn			
Species	1986[a] tri.	1987 plots	1988 plots	1989 plots	1991 plots	1996 plots	1986[b] tri.	1986[c] plots	1987 plots	1987[d] mor.	1988 plots	1989 plots	1991 plots	1996 plots
Maianthemum canadense			0.08	0.08		0.17					17	17		17
Mitella nuda			0.83	0.5	0.08	0.52					17	17	17	67
Orthilia secunda	<1					0.03	50							33
Osmorhiza chilensis		0.17	1.67	0.67	0.08	0.08			17		17	17	17	17
Petasites frigidus var. *palmatus*						0.03								33
Pyrola asarifolia	10		0.17	0.08	0.08	0.37	100				17	17	17	100
Rubus pedatus	<1	0.18	0.5	0.5	0.42	0.2	100		33		50	50	33	50
Rubus pubescens	<1	1.08	1.67	5.5	3.33	9.33	100		50	Sb	67	50	67	83
Maianthemum racemosum	3	0.22	0.75	0.83	0.58	0.75	100	17	67	R	67	50	50	67
Stellaria sp.						0.02								17
Streptopus lanceolatus var. *curvipes*	1	0.5	1.67		1.05	1	50		83		100		100	100
Taraxacum sp.						0.07								67
Tiarella trifoliata ssp. *trifoliate*		0.17	0.67	0.5	0.38	0.25	50		33		33	33	33	33
Tiarella trifoliata ssp. *unifoliata*	<1				0.17	0.1	50						17	33
Graminoids														
Calamagrostis canadensis		0.08	0.83	1.67	3.33	0.25			17		17	17	17	33
Carex mertensii						0.02								17
Carex sp.		5.37	22.2	16.3	5.75	0.22			100	Sb	100	100	100	67
Phleum sp.						0.02								17
Poaceae[e]					1								17	
Poaceae[f]						0.18								50
Poaceae[g]						0.02								17
Poaceae[h]						0.03								50
Mosses and Liverworts														
Aulocomnium palustre						0.05								50
Brachythecium hylotapetum						0.02								17
Brachythecium salebrosum						0.05								50
Bryum caespiticium						0.08								83
Bryum sp.						0.02								17
Cephaloziella sp.						0.02								17
Ceratodon purpureus						0.07								67
Dicranum scoparium						0.02	50							17
Drepanocladus uncinatus						0.02								17
Marchantia polymorpha				0.17								17		
Mnium sp.						0.02								17
Plagiomnium drummondii						0.02								17
Pleurozium schreberi						0.03								33
Pohlia nutans						0.02								17
Pohlia sp.						0.02								17

TABLE 10 *Continued*

	Cover (%)						Presence (%) and mode of establishment							
	Pre-burn		Post-burn				Pre-burn				Post-burn			
Species	1986[1] tri.	1987 plots	1988 plots	1989 plots	1991 plots	1996 plots	1986[b] tri.	1986[c] plots	1987 plots	1987[d] MOE	1988 plots	1989 plots	1991 plots	1996 plots
Polytrichum juniperinum			0.83	0.83	3.1	5.93					17	17	67	83
Ptilium crista-castrensis						0.1		50						33
Rhytidiadelphus triquetrus						0.02		50						17
Lichens														
Cladonia cariosa						0.02								17
Cladonia chlorophaea						0.03								33
Cladonia coniocraea						0.02								17
Cladonia fimbriata						0.02								17
Peltigera aphthosa						0.05								50
Peltigera canina						0.08								83
Peltigera didactyla						0.02								17
Peltigera sp.						0.02								17
TOTAL	100	48.3	56.7	81.7	86.3	90.8								

a Pre-burn cover of key species was based on sampling in three plots (one triangle) in 1986 by fire effects assessors. "p" indicates presence in at least one plot

b Pre-burn presence of key species was based on sampling in two triangles in 1986. "P" indicates presence in at least one triangle

c Pre-burn presence in plots (proportion of the six total) is inferred based on evidence of resprouting in 1987. "M" indicates species was present pre-burn (resprouted in 1987 but missed during pre-burn sampling in 1986)

d Mode of establishment (MOE): R = established by resprouting, S = established from seed, R/S = established by resprouting and by seed, Sb = established from seed bank

e Unknown grass species

f Grass described as "purple" in 1996

g Grass described as "droopy" in 1996

h Grass described as "thin or fine" in 1996

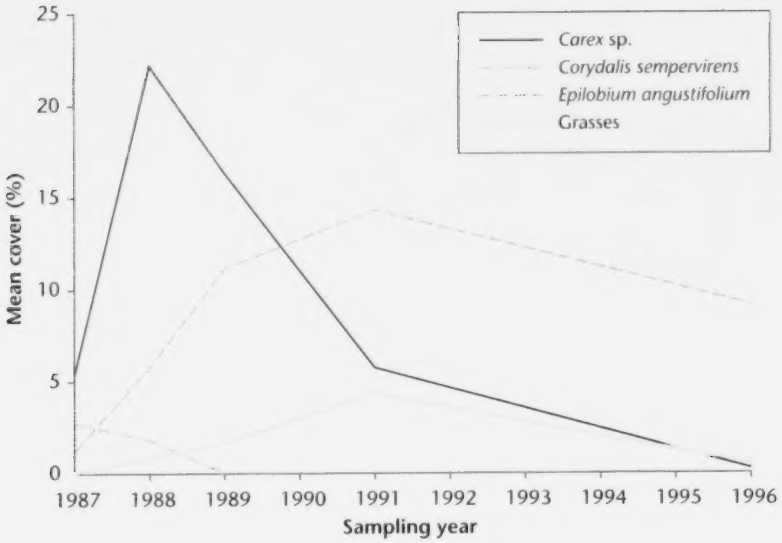

FIGURE 14 *Estimated mean cover of selected tall herbs over time.*

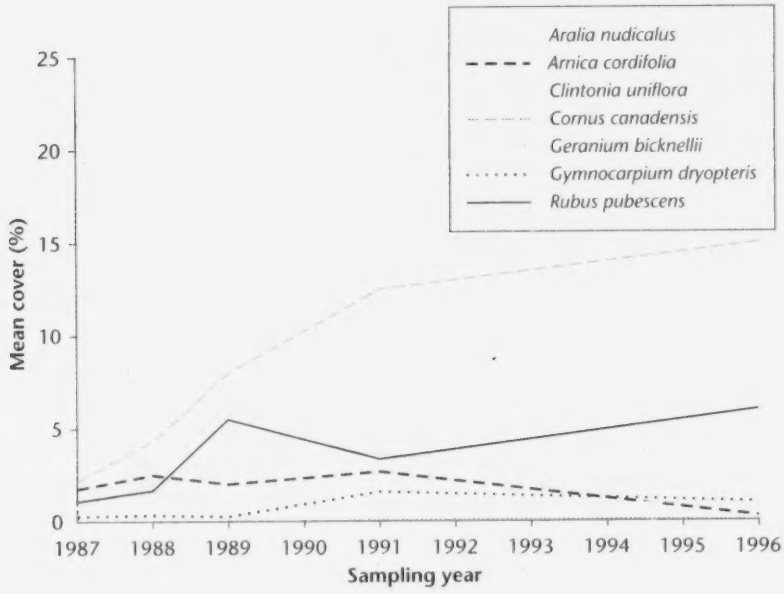

FIGURE 15 *Estimated mean cover of selected small herbs over time.*

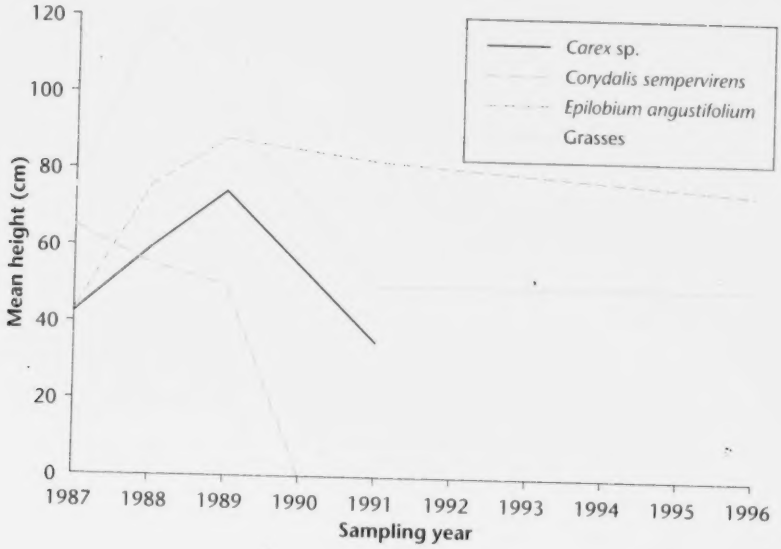

FIGURE 16 *Estimated mean height of selected herbs over time.*

4 CONCLUSIONS

The main conclusions of this study are:

- The fire was of moderate severity, consuming almost all of the fine fuel and 29% of the forest floor.
- The high observed DC (410) suggests that the deep forest floor layers were quite dry at the time of burning.
- Forest floor consumption and mineral soil exposure were less than predicted by the PFP, and woody fuel consumption was greater than predicted, suggesting that it must be modified to provide more accurate predictions of fire effects.
- Burning stimulated the germination of buried seeds of several species, including numerous berry-producing shrubs that are important for wildlife.
- Most of the native vascular plants on this site were sufficiently adapted to survive burning; at least some individuals of these species survived and resprouted.
- Some native plant species are negatively affected by fire and the exposed conditions found on cutblocks.
- The consumption of a high percentage of the forest floor led to the establishment of invasive species.
- Species adapted to open conditions (e.g., *Epilobium angustifolium, Cornus canadensis*) proliferated in the open cutblock.
- Ten years after burning, the site was dominated by lodgepole pine, spruce, trembling aspen, paper birch, *Rubus parviflorus, Spiraea betulifolia, Epilobium angustifolium,* and *Cornus canadensis.*

5 RECOMMENDATIONS

- Synthesis of fire effects, succession, and reforestation data from similar ecosystems in British Columbia.
- Continued monitoring of sites to ensure the collection of long-term data.
- Better calibration of the CFFWIS and Prescribed Fire Predictor for British Columbia conditions.

Abstract

Fire effects, understorey vegetation, and planted tree seedling responses to burning were monitored for 10 years after slashburning. Changes in floristic composition and structure (e.g., percent cover and height) were tracked. A standard fire weather station was used to determine fire weather codes and indices and to predict forest floor moisture content. Woody fuel loading and consumption and burn severity were determined using a line-intercept approach in standard fire effects assessment triangles and circular plots.

The burn was of moderate severity, resulting in little mineral soil exposure. Forest floor consumption and mineral soil exposure were less than predicted by the Prescribed Fire Predictor and woody fuel consumption was greater than predicted.

After the site was logged and burned, the ground-level vegetation structure shifted from a community dominated by bryophytes and small herbs to a young conifer forest with mosses, taller herbs, and shrubs. After 10 years, bryophyte cover was 15%, herb cover was 27%, and shrub cover was 15%. Some of the original forest species were lost. A number of new species established from the seed bank and sources outside of the plot.

The resilience of the native vascular species demonstrates that this is a fire-adapted ecosystem. The shrubs typical of wetter sites were not as well-adapted to burning as were the species more typical of drier forests, which would be expected, given the more frequent fires typical of the latter.

The planted lodgepole pine and spruce seedlings met free-growing requirements by 10 years after burning. Average conifer height at that time was 2.1 m. Lodgepole pine was the dominant species, averaging 3 m tall, while competing vegetation averaged approximately 50 cm tall. There was a small hardwood component, dominated by paper birch and trembling aspen.

1.1 Background

Clearcutting and slashburning have been widely practised in British Columbia, but little is known about subsequent patterns of vegetation development or how management activities, particularly slashburn severity, influence these patterns. Hamilton and Yearsley (1988) provided preliminary models of forest vegetation succession that helped facilitate integration of forest regeneration with wildlife habitat and biodiversity needs in the Sub-Boreal Spruce (SBS) zone and assisted in the development of a seral classification within the biogeoclimatic ecosystem classification (BEC) system.

Standard methods to monitor fire effects have been developed (Trowbridge et al. 1994). The Prescribed Fire Predictor is a tool that can be used to predict fire effects based on fire weather indices, which estimate forest floor and woody fuel moisture content (Muraro 1975; Van Wagner 1987).

This is the 10-year report on the Genevieve Lake site (E.P. 1093.11). This site is one of several in British Columbia where fire effects, vegetation, and tree responses were monitored for 10 years after clearcutting and slashburning in permanent plots. This study is among very few in British Columbia to record slashburning severity and collect post-burn data on all vegetation species in permanent plots over several years. Similar data are being collected on several sites in the Northern Interior Forest Region. These results will be combined to form the basis of a preliminary report on early forest succession in the SBS zone.

1.2 Objectives

The objectives of this study are:

1. to document the effects of a prescribed slashburn on the forest floor, fuels, and vegetation;
2. to determine the relationships between predicted and actual woody fuel and duff consumption and mineral soil exposure;
3. to quantify and describe changes in percent cover, height, species composition, and diversity of vegetation following burning;
4. to describe the growth of planted lodgepole pine (*Pinus contorta* var. *latifolia*) and hybrid white spruce (*Picea glauca* × *engelmannii*) seedlings after burning; and
5. to determine the relationships between fire effects, vegetation levels, and planted tree seedling growth.

1.3 Study Area

This site (Opening number 93G029-32) is located in the Prince George Forest District of the Northern Interior Forest Region, in the Bowron River valley southeast of Prince George, at 53°15′35″ N, 122°22′20″ W (Figures 1 and 17). It is at 920 m elevation in the moist wet subzone of the Sub-Boreal Spruce zone (SBSmw), close to the transition with the moist cool (SBSmk) subzone. It is a fairly level, moist, rich site with a periodically high water table. The site contains areas of SBSmw/06 (*Picea glauca* × *engelmannii*—*Gymnocarpium dryopteris*) and SBSmw/07 (*Picea glauca* × *engelmannii*—*Lonicera involucrata*—*Gymnocarpium dryopteris*) site series.

The site was clearcut in the winter of 1985–86 when snow cover was deep enough to prevent disturbance of the forest floor and destruction of understorey vegetation across most of the site. It was burned on September 16, 1986. Lodgepole pine and hybrid white spruce seedlings were planted in 1987.

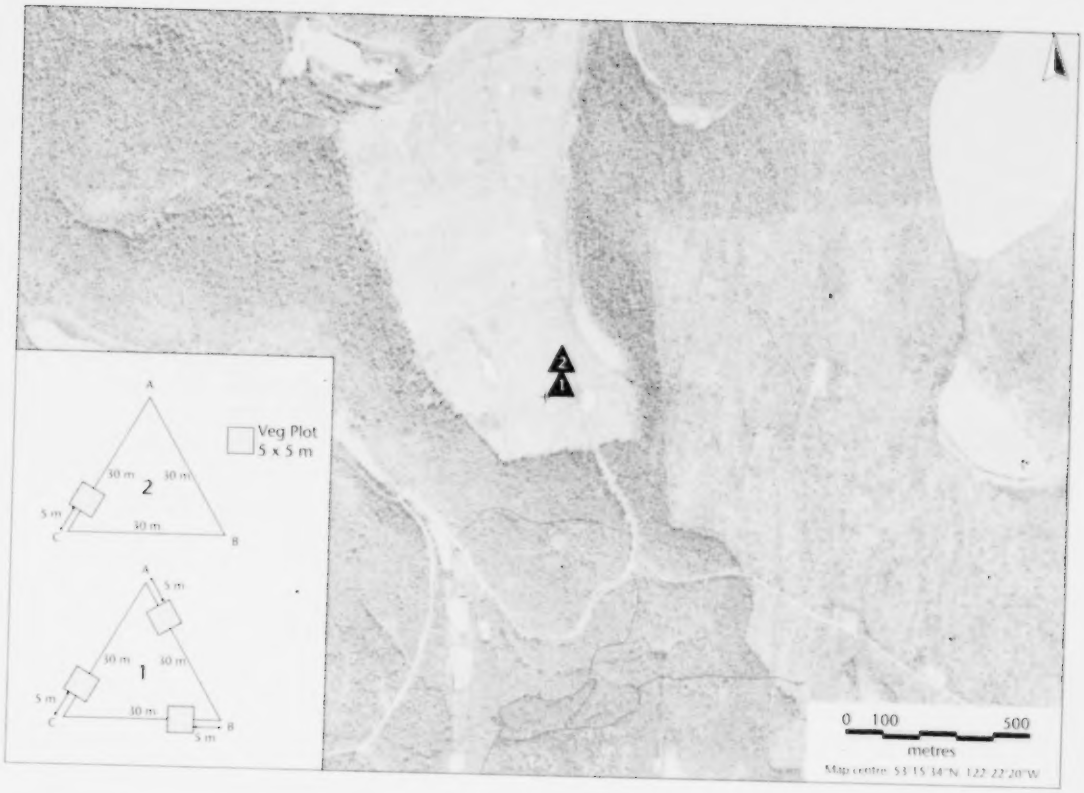

FIGURE 17 *Orthophoto of the site and layout of fire effects assessment triangles on the site (layout of vegetation plots inset).*

2.1 Data Collection

Data on fire effects and vegetation responses to burning were collected on this site using a combination of fire effects assessment triangles and permanent vegetation plots. Sampling was initiated in 1987 prior to burning, and continued for 10 years.

2.1.1 Fire effects Two fire effects assessment triangles (30 m per triangle side for a total of 180 m of line-intersect sampling) were installed on the site by J. Muraro and his crew following standard methods (Trowbridge et al. 1994). Depth of burn (DOB) pins were installed at 5-m intervals along all three sides of the triangles, except at the vertices (30 pins/triangle or 60 in total).

In addition, eight circular plots (4 m in radius) were installed on the site. In each plot, woody fuel were sampled along 16 m of line intersect (i.e., 4-m lines were established from the centre of a plot along each cardinal direction) for a total of 128 m of line. Sixteen DOB pins were installed along the lines at 1-m intervals, for a total of 128 pins in the eight plots.

The DOB and remaining duff depth were measured at each pin after burning. Woody fuel loading was estimated prior to burning, and consumption was determined by resampling the transects after the fire. Weighted averages were calculated using values derived from these two sampling methods, with values weighted by the sampling intensity. A grand total of 308 m of line and 220 DOB pins were sampled on the site.

2.1.2 Vegetation Four 5 × 5-m permanent plots were established in the summer of 1987, a year after the site was slashburned. These plots were superimposed on the two fire effects assessment triangles (Figure 17).

The dominant plant species within the triangles were listed by J. Muraro and his crew prior to burning in 1987. Complete post-burn vegetation data in the plots were recorded in July or August of 1987, 1988, 1989, 1991, and 1996 (1, 2, 3, 5, and 10 years after burning; Figure 18). Estimated percent cover of each plant species in each plot was recorded. Mean height was collected for selected herb and shrub species. The mode of establishment, either from seed or resprouting from surviving plant parts, was recorded in 1987 for selected species. Cover of all vascular plant species was recorded, but few non-vascular plants were recorded until 1996, because data collectors were not sufficiently trained to recognize rarer species. In 1996, non-vascular plants were collected and identified by F. Boas.

Percent cover is defined as an estimate of the actual area covered by projecting the leaves of the species onto the ground, not the area defined by the outline of the plants. Percent cover for all species combined (total) was also recorded in the field. Non-vascular plants are included in the total percent cover estimates.

Height was recorded for selected herbs, all shrubs, and all trees. Only vascular plants were included in the total height values. Height was considered to be the average height of a species in the plot, taking into account (i.e., weighting by) the percent cover of individual plants with different heights. This was done by taking several measurements where there was considerable variation, and estimating the mean. For example, if 5% of the species cover was 150 cm tall but the rest was only 90 cm tall, the estimated height value was much closer to 90 cm than to 150 cm.

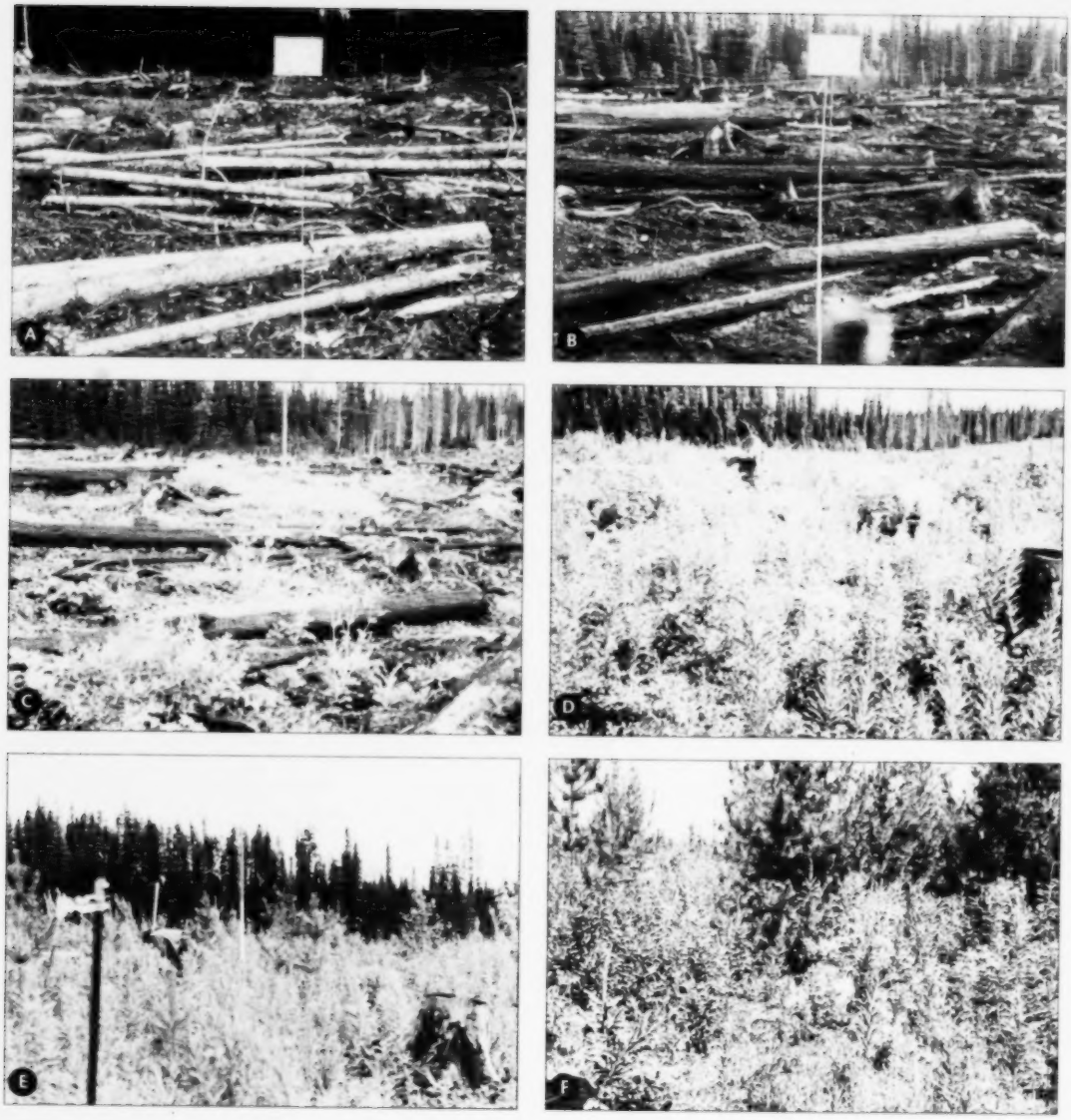

FIGURE 18 *Photos of the site (A) immediately before burning, (B) immediately after burning, (C) 1 year after burning, (D) 3 years after burning, (E) 5 years after burning, and (F) 10 years after burning.*

A mean shrub (excluding tree species) height was calculated using the following formula, which weights the average heights by cover. The cover and mean height were recorded for conifer and hardwood species.

$$\text{mean shrub height} = \frac{\sum_{\text{shrub species } S}^{\text{all shrub species}} (\%\ \text{cover}_S) \times (\text{mean height}_S)}{\sum_{\text{shrub species } S}^{\text{all shrub species}} \%\ \text{cover}_S}$$

2.2 Data Analysis

Pre-burn vegetation data were compared to the appropriate units in the provincial biogeoclimatic ecosystem classification (BEC) database and the field guides for the southern portions of the Northern Interior Forest Region (DeLong 2003) to confirm the field-based site series classification.

Graphs and descriptive statistics are used to present and assess the changes in vegetation and planted spruce over time.

Mean percent cover was calculated as the sum of the cover percentages for a given species, divided by the total number of sample plots to provide a measure of abundance over the whole site. Mean height was calculated as the sum of the (mean) heights recorded for a species, divided by the number of plots in which the species was recorded. Percent presence, an expression of frequency, was the percentage of plots in which each species occurred.

The standard error of the mean for pre- and post-burn fuel loading and consumption, pre- and post-burn duff depth, depth of burn, and consumption percent was calculated using the individual values from the two triangles and four plots.

3.1 Fire Effects

Canadian Forest Fire Weather Index System codes and indices at the time of burning (Van Wagner 1987) were: Fire Weather Index (FWI) = 3, Fine Fuel Moisture Content (FFMC) = 80, Duff Moisture Code (DMC) = 18, and Drought Code (DC) = 454.

The site average pre-burn forest floor depth was 6.97 cm. The depth of burn (DOB) was 1.76 cm, equivalent to consumption of 24.9% of the forest floor (Table 11). Total woody fuel loading prior to burning was 188.1 tonnes/ha and total consumption was 58.6%. Fine fuel (< 7 cm diameter) consumption was 98.1% (Table 12).

TABLE 11 *Pre-burn litter depth, pre- and post-burn depth of the forest floor, depth of burn, and percent consumption for the whole site (mean and standard error), plots only (mean), and triangles only (mean)*

Source	Pre-burn litter depth (cm)	Pre-burn depth of forest floor (cm)	Post-burn depth of forest floor (cm)	Depth of burn (cm)	Duff consumption (%)
Site average (n = 220 pins)	4.06 (0.68)	6.97 (0.57)	5.2 (0.43)	1.76 (0.28)	24.9 (2.7)
Plots only (8 plots; n = 160 pins)	4.53	6.5	4.7	1.75	26.3
Triangles only (2 triangles; n = 60 pins)	2.16	9.0	7.2	1.78	19.5

TABLE 12 *Total woody fuel loading and consumption (mean and standard error) for the whole site, and mean values for plots only and triangles only*

Source	Total pre-burn loading of all woody fuel (tonnes/ha)	Total consumption of all woody fuel (%)	Consumption of fine fuel (< 7 cm diameter) (%)
Site average (n = 308 m line)	188.1 (31.7)	58.6 (4.0)	98.1 (0.57)
Plots only (n = 128 m line)	195.3	59.5	98.5
Triangles only (n = 180 m line)	159.0	55.1	96.2

The pre-burn forest floor depth in the two triangles was 9.0 cm, DOB was 1.78 cm, and consumption was 19.5%. (Table 11). Total woody fuel loading in the triangles was 159.0 tonnes/ha pre-burn and total consumption was 55.1%. Fine fuel consumption was 96.2% (Table 12).

In the eight plots, the pre-burn forest floor depth was 6.5 cm, DOB was 1.75 cm, and consumption was 26.3% (Table 11). Total woody fuel loading was 195.3 tonnes/ha pre-burn and total consumption was 59.5%. Fine fuel consumption was 98.5% (Table 12).

Actual forest floor consumption and mineral soil exposure (based on the site average) were much less than predicted by the Prescribed Fire Predictor. Actual fuel consumption (for all woody fuel) was 58.6%, which was considerably higher than predicted for fuels < 22 cm in diameter (25%) (Table 13). Approximately 25% of the fuel > 7 cm diameter was > 22 cm in diameter. The consumption of these large pieces was generally less than that of the smaller pieces. Therefore the consumption of total woody fuel consumption < 22 cm in diameter is expected to be even higher than 58.6% (the observed consumption of all fuels), and therefore the discrepancy between observed and PFP-predicted values would have been even wider than that observed.

TABLE 13 *Predicted and actual duff and fuel consumption and mineral soil exposure using weather station and measured forest floor moisture content*

Duff consumption (%)		**Mineral soil exposure (%)**		**Total woody fuel consumption (%)**		**Consumption of fine fuel (< 7 cm diameter) (%)**	
Pred.[a]	**Actual**[b]	**Pred.**[a]	**Actual**[b,c]	**Pred.**[a,d]	**Actual**[b]	**Pred.**[a,e]	**Actual**[b]
45	24.9	30	9.5	25	58.6	65	98.1

a Predicted based on Prescribed Fire Predictor (Muraro 1975)
b Actual values based on site average fuel triangle measurements
c Based on site total n = 220 pins
d Predicted consumption of woody fuel < 22 cm in diameter
e Predicted consumption of woody fuel < 7 cm in diameter

3.2 Vegetation

The number of taxa (species, subspecies, and plants identified to family) increased over time (Table 14). Over the duration of the study, the number of shrub taxa increased from eight to 12 and the number of herb taxa increased from 15 to 30. These increases reflect both the establishment of new species over time and the fact that the plant samples were verified by an expert in year 10 who was able to identify more species than would have been identified to this level earlier.

TABLE 14 *Number of taxa by lifeform in each year*

	Lifeform				
Year	**Trees**	**Shrubs**	**Herbs**[a]	**Non-vascular plants**[b]	**Total**
1987	1	8	15	0	24
1988	2	6	16	1	25
1989	2	9	14	3	28
1991	3	9	18	3	33
1996	5	12	30	8	55
# taxa/lifeform	5	13	37	10	65[c]

a Includes graminoids
b Includes mosses, liverworts, and lichens
c Total number of taxa recorded over all years and lifeforms

Tree cover increased steadily over time as the planted lodgepole pine and spruce trees became established. Planted tree seedlings dominated the site by year 10. Herb and shrub percent cover and height increased initially, and then declined as the conifers became dominant (Table 15; Figures 18 and 19).

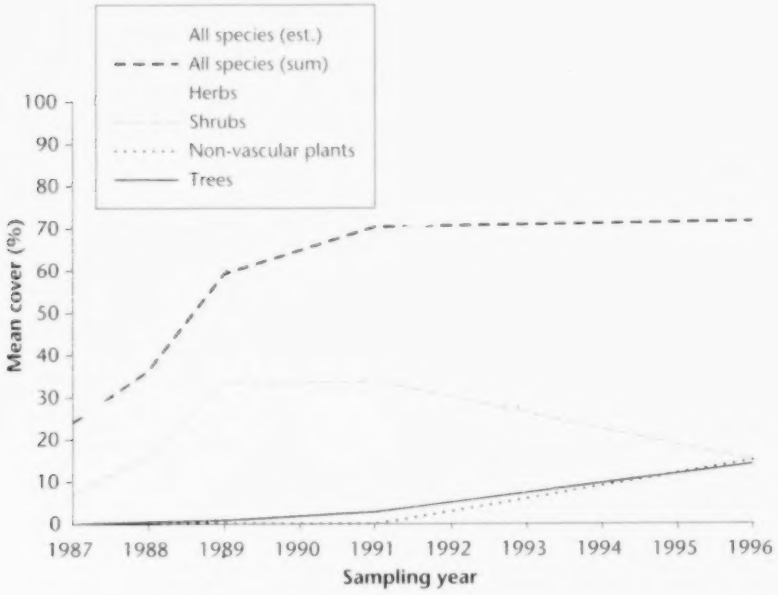

FIGURE 19 *Estimated mean percent cover of life forms and all species over time.*

TABLE 15 *Mean cover and percent presence of vegetation pre-burn and 1, 2, 3, 5, and 10 years after burning on the Genevieve Lake site (n = 4 plots; **bold** values are species established from buried seed in 1987)*

	Cover (%)						Presence (%)				
	Post-burn				Pre-burn	Post-burn				
Species	1987	1988	1989	1991	1996	1986[a]	1987	1988	1989	1991	1996
Trees											
Abies lasiocarpa					0.15						50
Betula papyrifera	0.03	0.28	0.28	1.25	0.68	+	25	50	75	75	100
Picea glauca × *engelmannii*				0.05	1.63					25	75
Pinus contorta var. *latifolia*		0.38	0.38	1.5	11.5			50	50	50	75
Populus tremuloides					0.13						25
Shrubs											
Amelanchier alnifolia					0.03						25
Lonicera involucrate						+					
Prunus pensylvanica			0.25	0.5	1				50	50	75
Ribes lacustre	**0.28**		0.28	0.63	0.5	+	**75**		75	75	100
Ribes laxiflorum	**0.25**	0.5	1	0.5	0.13		**50**	25	25	25	25
Rosa acicularis	1.63	1.5	2.38	4.5	1.75	+	75	50	75	75	75
Rubus idaeus	**1.75**	8.25	19.25	19.25	6.75		**100**	100	100	100	100
Rubus parviflorus	1.25	0.75	1.5	1.5	1.25	+	25	25	50	50	25
Salix sp. 1[b]			0.13	0.25	0.5				25	25	50
Salix sp. 2[c]					0.75						25
Sambucus racemosa	**1.03**	5	8	6.25	2.25		**100**	100	100	100	100
Spiraea betulifolia	0.38	0.38	0.38	0.25	0.25	+	50	50	50	25	50
Vaccinium membranaceum	0.38					+	50				
Vaccinium sp.[d]					0.03						25
Herbs											
Achillea millefolium					0.33						100
Anaphalis margaritacea				0.03	0.13					25	25
Antennaria sp.					0.13						25
Aralia nudicaulis	0.5	0.5	0.15	0.35	0.65		100	50	50	75	100
Athyrium filix-femina						+					
Castilleja sp.					0.03						25
Cirsium sp.			0.13	0.03	0.18				25	25	75
Clintonia uniflora	0.18	0.13	0.18	0.03	0.15		75	25	75	25	50
Cornus canadensis	1.53	2.25	3	4.75	6.25	+	100	100	100	100	100
Corydalis sempervirens	**0.5**	1.28	0.05				**75**	100	50		
Crepis sp.[e]				0.03	2					25	25
Epilobium angustifolium	0.15	2.25	5.25	15.5	9.5	+	50	100	100	100	100
Epilobium ciliatum	**0.03**	0.13	0.28				**25**	25	50		
Epilobium sp.		0.03						25			
Equisetum sylvaticum		0.03	0.25	0.25	0.5	+		25	25	25	25
Geranium bicknellii[f]	**9.5**	0.88	0.05		0.05		**100**	100	50		50
Gymnocarpium dryopteris	0.13				0.05		25				50
Hieracium albiflorum				0.03	0.43					25	100
Hieracium aurantiacum					2.75						75
Hieracium sp.[g]			0.25	0.15	0.38				25	50	50
Linnaea borealis				0.03	0.13					25	25
Lupinus sp.	**0.03**				0.78		**25**				100

TABLE 15 *Continued*

	Cover (%)						Presence (%)				
	Post-burn				Pre-burn		Post-burn				
Species	**1987**	**1988**	**1989**	**1991**	**1996**	**1986**[a]	**1987**	**1988**	**1989**	**1991**	**1996**
Orthilia secunda					0.03						25
Oplopanax horridus						+					
Prunella vulgaris	**1.25**	0.53	0.13	0.05			**25**	50	25	25	
Rubus pedatus		0.03						25			
Smilacina stellata					0.15	+					50
Streptopus roseus		0.53		0.13	0.28	+		75		25	50
Taraxacum sp.		0:03	0.15	0.15	0.28			25	50	50	75
Tiarella trifoliata var. *trifoliata*		0.15	0.03	0.05	0.18			50	25	25	50
Tiarella trifoliata var. *unifoliata*	0.25			0.18	0.13	+	50			50	100
Veratrum viride	0.03	0.25				+	25	25			
Viola sp.	0.13			0.03	0.1		25			25	100
Unknown herb species	0.13						25				
Graminoids											
Carex foenea					0.03						25
Carex sp.[b]	**2.75**	10.25	15.5	12	0.43		**100**	100	100	100	100
Festuca occidentalis					1.25						25
Poaceae #6[j,k]					0.03						25
Poaceae #8[j,k]					0.08						50
Mosses, Liverworts and Lichens											
Aulocomnium palustre					0.03						25
Brachythecium sp.					0.03						25
Bryum caespiticium					0.03						25
Ceratodon purpureus[l]					7						100
Dicranum sp.			0.03	0.03					25	25	
Marchantia polymorpha			0.03	0.03					25	25	
Peltigera canina					0.03						25
Peltigera sp.					0.03						25
Pleurozium schreberi					0.03						25
Polytrichum juniperinum[m]		0.03	0.03	0.18	8			25	25	50	100
TOTAL	25	34	56	69	85		100	100	100	100	100

a + = listed as present prior to burning by J. Muraro and his crew. Only dominant species were recorded
b Described as "shiny yellow" for plot 2C in 1996
c Described as "fuzzy" for plot 2C in 1996
d Probably *V. membranaceum*
e Described as "yellow" in 1991 and 1996
f May be a different species in 1996
g Labelled "yellow" in some years and plots, and not in others
h Specimens collected from the site in 1996 were identified as *C. aenea*
i Described in 1996 as "droopy" but no samples identified
j Described in 1996 as "long awn." Specimens with this description collected in one plot were *Festuca occidentalis*
k These are members of the Poaceae family that could not be identified beyond the family level; the numbers refer to the specimen number
l Described in 1996 as "tiny brown moss" and assumed to be *Ceratodon purpureus*
m Assumed all *Polytrichum* species were *P. juniperinum*

Three shrubs, *Rosa acicularis*, *Spiraea betulifolia*, and *Vaccinium membranaceum*, re-established by resprouting after the fire. *Ribes laxiflorum*, *Rubus idaeus*, and *Sambucus racemosa* established from buried seeds. *Ribes lacustre* and *Rubus parviflorus* both resprouted and germinated from buried seed (Table 15). The shrub layer was dominated for the first 10 years by *Rubus idaeus*, yet *Sambucus racemosa* spread rapidly from buried seeds, then declined as many of the germinants died in the first few years (Figures 20 and 21). Virtually all the shrubs, with the exception of *Prunus pensylvanica*, declined in cover once the planted seedlings began to dominate the site (Figure 22) and all except *P. pensylvanica* declined in height (Figure 21). *Oplopanax horridus* was intolerant of the conditions on the burned cutblock and disappeared after burning along with *Athyrium filix-femina* and *Lonicera involucrata* (Table 15).

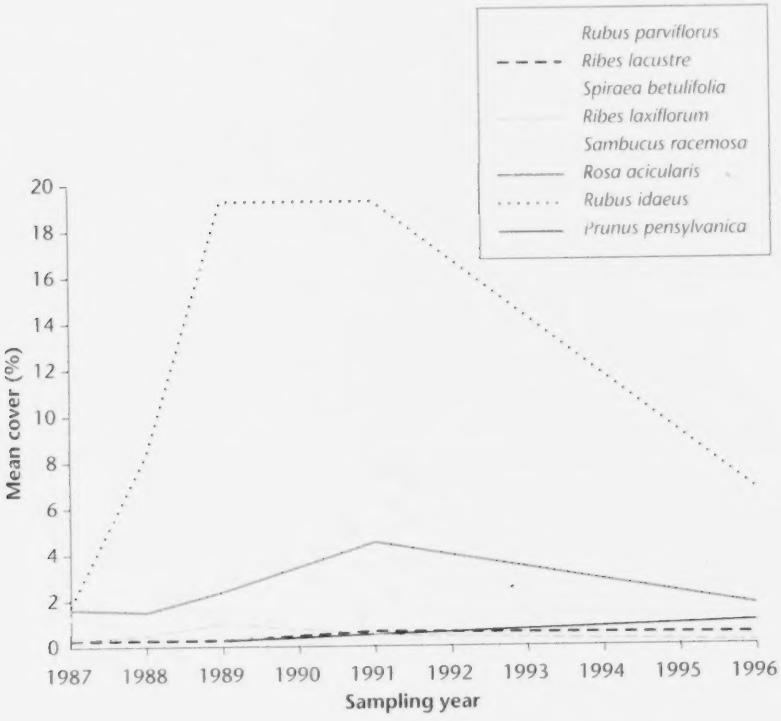

FIGURE 20 *Estimated mean percent cover of selected shrubs over time.*

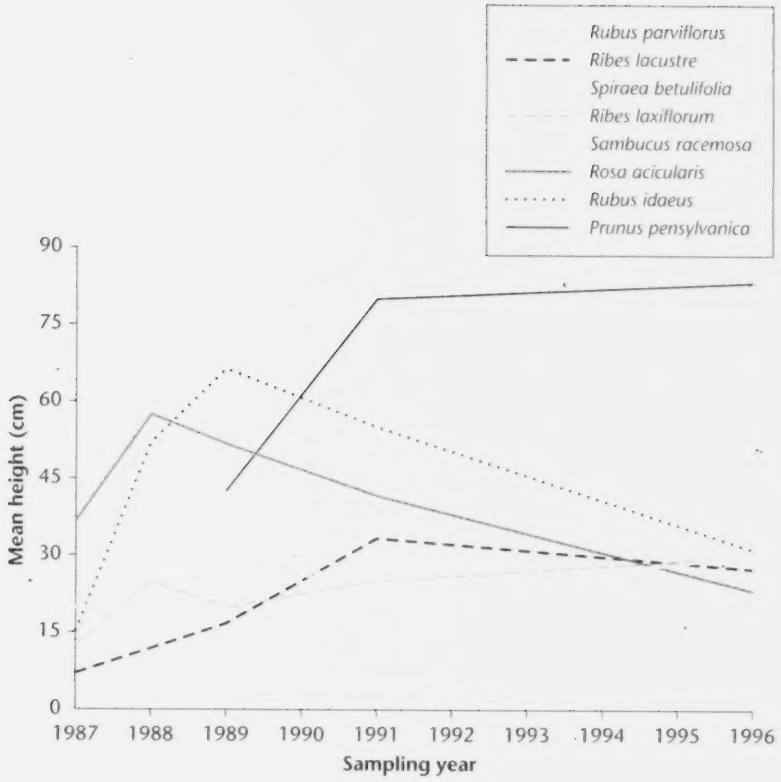

FIGURE 21 *Estimated mean height of selected shrubs over time.*

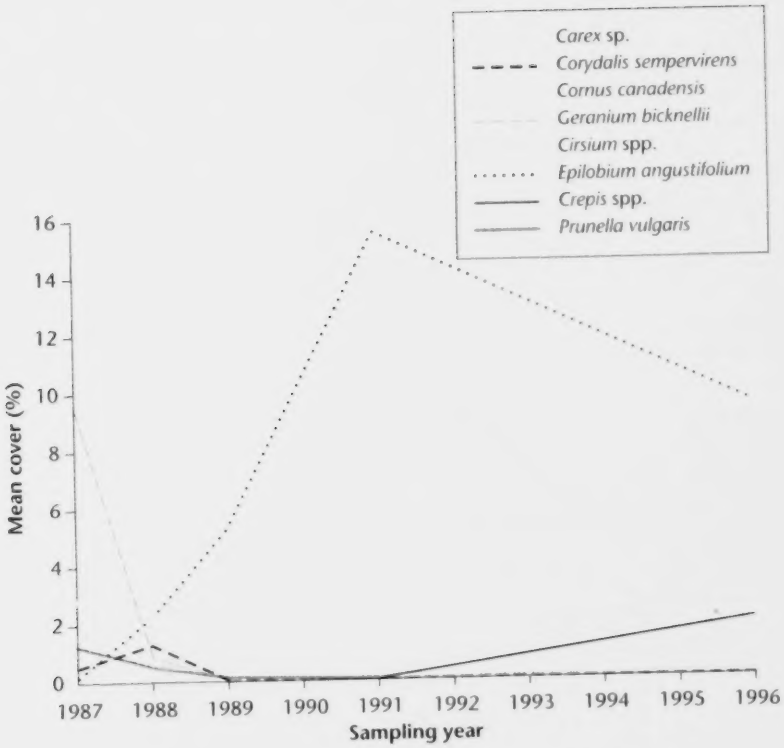

FIGURE 22 *Estimated mean percent cover of selected herbs over time.*

The three herb species present in the first post-burn year but gone by the fifth (*Geranium bicknellii, Epilobium ciliatum,* and *Corydalis sempervirens*) are typical ephemeral species with long-term seed dormancy (Table 15). *Carex* sp., *Lupinus* sp., and *Prunella vulgaris* also established from buried seeds. *Carex* sp. persisted until year 10 (Table 15). The increase in numbers of herb species was mainly due to the invasion of "weedy" species and plants typical of open sites that gradually established from wind-dispersed seeds (i.e., *Hieracium* spp., *Crepis* sp., *Cirsium* sp., *Taraxacum* sp., *Anaphalis margaritacea, Antennaria* sp., and *Achillea millefolium*). Rapid establishment of *Epilobium angustifolium* from "pseudo-rhizomes" and seeds was observed.

Epilobium angustifolium, Cornus canadensis, and *Carex* sp. dominated the herb layer for 10 years (Table 15), by which time the cover of *E. angustifolium* had declined and *Carex* sp. had virtually disappeared. The cover of *Cornus canadensis* continued to increase. Most other herbs maintained a relatively low cover (Figure 22).

4 CONCLUSIONS

The main conclusions of this study are as follows:

- The fire was of moderate severity, consuming almost all of the fine fuel and 1.7 cm, or close to 25%, of the forest floor.
- The high observed DC (454) suggests that the deep forest floor layers were quite dry prior to burning.
- Forest floor consumption and mineral soil exposure were less than predicted by the PFP and woody fuel consumption was greater than predicted, suggesting that the PFP tool should be improved to predict fire effects more accurately.
- The consumption of a high percentage of the forest floor led to the establishment of invasive species.
- Burning stimulated the germination of buried seeds of several species, including numerous berry-producing shrubs that support important wildlife habitat.
- Most of the native vascular plants on this site were sufficiently adapted to survive burning, since at least some individuals survived and re-sprouted.
- Some native plant species are negatively affected by fire and the exposed conditions found on cutblocks.
- Species of open conditions (e.g., *Epilobium angustifolium, Cornus canadensis*) proliferated in the open cutblock.
- Eleven years after burning, the site was dominated by lodgepole pine trees, *Rubus idaeus, Epilobium angustifolium,* and *Cornus canadensis.*

5 RECOMMENDATIONS

- Better calibration of the CFFWIS and Prescribed Fire Predictor for interior British Columbia conditions.
- Synthesis of fire effects, succession, and reforestation data from similar ecosystems in British Columbia.
- Continued monitoring of sites to ensure the collection of long-term data.

Abstract

Vegetation and early conifer development were monitored for 10 years after slashburning on this site near Prince George in the Sub-Boreal Spruce (SBS) zone. There were more species in the tenth year after burning than the first for all lifeforms except trees.

The fire was of moderate severity, consuming almost half of the total fuel, almost all of the fine fuel, and close to 28% of forest floor. The relatively high Drought Code (314) suggests that the deep forest floor layers were quite dry at the time of burning. Forest floor consumption and mineral soil exposure were less than predicted by the PFP, and woody fuel consumption was greater than predicted. The consumption of a high percentage of the forest floor led to significant mineral soil exposure, which facilitated the establishment of invasive species.

Total percent cover increased from around 75% in the first post-burn year and levelled off at 92% 5 years after burning. Shrubs were always more abundant than herbs. Three of the six shrub species present in the first year after burning resprouted from underground meristems, while the rest germinated from seeds from the soil seed bank. The increase in herbs was mainly due to the establishment of "weedy" species with wind-dispersed seeds such as *Epilobium angustifolium* and *Calamagrostis canadensis*.

Planted spruce seedlings covered approximately 15% of this site 10 years after burning. Despite the rapid re-establishment and high cover of *Rubus parviflorus*, the planted spruce appear not to have been adversely affected by the vegetation. On average, trees were as tall as the shrubby and herbaceous vegetation by the second post-burn year, and twice as tall by the fifth post-burn year, suggesting that most were probably free-growing. By the tenth post-burn year (9 years after planting), trees were five times the height of the average shrubs and taller than all species on site except Sitka alder.

1.1 Background and Rationale

Development of sustainable forest management practices requires an understanding of the short- and long-term impacts of harvesting and site preparation on all forest vegetation. Clearcutting and slashburning have been widely practised in British Columbia, but little is known about subsequent patterns of vegetation development or how management activities, particularly slashburn severity, influence these patterns. The strong positive response to FRDA Report 018 (Hamilton and Yearsley 1988) indicates that predictive models of forest vegetation succession are essential to the development of management prescriptions that meet such integrated resource use objectives as forest regeneration, providing wildlife habitat, and maintaining biodiversity. The information in this report will also contribute to the development of a seral classification within the biogeoclimatic ecosystem classification (BEC) system.

Succession information can be gathered in two ways. The chronosequence method involves sampling many sites of different ages (years since disturbance). The second method involves repeated measurement of vegetation in permanent plots at regular intervals. The advantage of the chronosequence method is that it is possible to reconstruct a successional sequence based on a single year's data collection. This was the approach we took with the FRDA 018 project. The difficulty is finding and identifying sites that are ecologically similar, and which have undergone the same type and severity of disturbance (e.g., harvesting and site preparation). With the permanent plot approach, it is possible to select ecologically similar sites and measure the impact of the chosen disturbance, but it takes many years to collect enough data to determine successional patterns.

This site is one of several in the Sub-Boreal Spruce (SBS) zone where vegetation and planted conifer growth is being monitored after clearcutting and slashburning. The study is among very few in British Columbia to record slashburning severity, planted conifer growth, and both pre-burn (in some cases pre-harvest) and several years of post-burn data on all vegetation species in permanent plots. Although similar data are being collected on several sites in the Northern Interior Forest Region, and a number of other chronosequence and combined studies have been done, very little of this information has been published. Results from our sites will be combined to form the basis of a preliminary report on early forest succession in the SBS zone, and will be compared to the patterns derived from a set of similar sites we are monitoring in the Engelmann Spruce–Subalpine Fir (ESSF) zone.

1.2 Objectives

The objectives of this study are:

1. to quantify and describe changes in percent cover, height, species composition, and diversity of vegetation over time;
2. to quantify and describe the growth of planted spruce seedlings over time; and
3. to assess the interactions among burn severity (depth of burn), vegetation development, and planted spruce growth.

2.1 Study Area

This site (CP 936043-7) is located in the Prince George Forest District of the Northern Interior Forest Region, in the Bowron River valley southeast of Prince George (Figure 1). The site is situated at approximately 1200 m elevation in the very wet cool subzone of the Sub-Boreal Spruce zone (SBSvk). The site was classified as the zonal (*Picea glauca* × *engelmannii*—*Oplopanax horridus*) SBSvk/01 site series, supporting the representative vegetation association prior to logging. Plots are located on a moderately steep (35%) east-facing slope.

The site was clearcut in the winter of 1985–86 when snow cover was deep enough to prevent disturbance of the forest floor and destruction of understorey vegetation across most of the site (Figure 23). The site was burned on August 28, 1986 and planted in 1987.

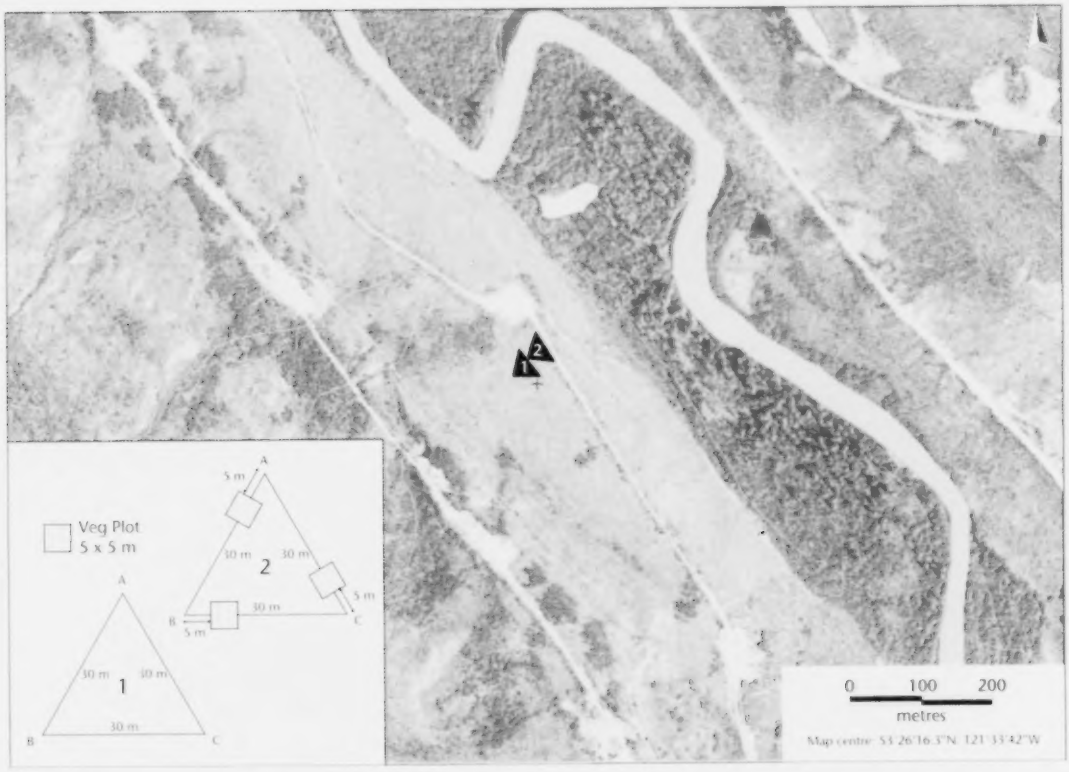

FIGURE 23 *Orthophoto of the site and layout of vegetation plots and fire effects assessment triangles on the site.*

2.2 Data Collection

Three 5 × 5-m permanent plots were established in the summer of 1987 after slashburning. The plots were positioned midway along each arm of one of two operational fire effects assessment triangles that were installed on the site following standard procedures (Trowbridge et al. 1994)(Figure 24). Depth of burn (DOB) and fuel consumption were assessed and dominant plant species presence was noted by J. Muraro and crew.

Vegetation data were collected in July or August of 1987, 1988, 1989, 1991, and 1996 (1, 2, 3, 5, and 10 years after burning; Figure 24). Estimated percent cover of each plant species in each plot was recorded in all sampling years. Mean height was collected for selected herb and shrub species only. The mode of establishment, either from seed or resprouting from surviving plant parts, was recorded in 1987 for selected species. This was determined by carefully excavating around the roots of the new plants to determine if they were attached to rhizomes or originated from seed. All vascular plant species were recorded, but few non-vascular plants were recorded until 1996 because data collectors were not sufficiently trained to recognize rarer species, and also because these taxa tend to take much longer to recover from fire, so there may have been very few to record. In 1996, non-vascular plants were collected and identified by bryophyte expert F. Boas. Therefore, conclusions about changes in diversity of bryophytes and lichens cannot be drawn from this study.

Percent cover was defined as an estimate of the actual area covered by projecting the leaves of the species onto the ground, not the area defined by the outline of the plants. Percent cover for all species combined (total) was also recorded in the field, but cover totals for herbs and shrubs were never recorded. Non-vascular plants are included in the total percent cover estimates.

Height was recorded for selected herbs and all shrubs and, in some years, all species combined (total). Only vascular plants are included in the total height values, since non-vascular plants contributed little to the aboveground structure of forest vegetation. Height was considered to be the average height of a species in the plot, taking into account the proportionate cover of individual plants with different heights. This was done by taking several measurements where there was substantial variation, and estimating the mean. For example, if 5% of the species cover was 150 cm tall but the rest was only 90 cm tall, then the estimated height was much closer to 90 cm than to 150 cm.

Since heights were recorded for all shrub species, it was possible to generate a mean height for this lifeform using the following formula, which weights the height by cover:

$$\text{mean shrub height} = \frac{\sum_{\text{shrub species } s}^{\text{all shrub species}} (\%\ \text{cover}_s) \times (\text{mean height}_s)}{\sum_{\text{shrub species } s}^{\text{all shrub species}} \%\ \text{cover}_s}$$

Tree species in the shrub layer were not included in the calculations for shrub height. Average herb height was not calculated because not all species were measured.

In 1987, 13 operationally planted interior spruce (*Picea glauca* × *engelmannii*) seedlings were tagged for measurement in and around the vegetation plots. Two more trees were added in 1988 for a total of 15 tagged trees. The

FIGURE 24 *Photos of the site (A) pre-burn, (B) immediately after burning, (C) 1 year after burning, (D) 2 years after burning, (E) 3 years after burning, (F) 5 years after burning, and (G) 10 years after burning.*

mean percent cover and height of planted spruce were calculated as the percent of the plot covered by the sum of canopy areas of trees in the plots. Heights, root collar caliper, and canopy area of planted spruce seedlings were measured immediately after planting in 1987, and again in 1988, 1989, 1991, and 1997. Two perpendicular diameters of the canopy (from tip to tip of the longest branches) were measured to calculate canopy area as area = πr^2, where r (radius) was the mean of the two canopy measurements, divided by two. In 1988, 1989, and 1991, plots were sampled in July or August, likely before the trees finished growing for that year. The tenth-year sampling was done in the spring of 1997 before growth had begun, inclusive of all growth in 1996.

2.3 Data Analysis

Pre-burn vegetation data were compared to the appropriate units in the provincial biogeoclimatic ecosystem classification (BEC) database and a draft version of the field guide update for the Northern Interior Forest Region to confirm the site series classification (DeLong 2003).

The data collected from this site are descriptive in nature because no formal experimental design was employed. Graphs and descriptive statistics, rather than formal analyses, are used to present and assess the changes in vegetation and planted spruce over time.

Mean percent cover was calculated as the sum of the cover values for a given species, divided by the total number of sample plots to provide a measure of abundance over the whole site. Mean height was calculated as the sum of the heights recorded for a species, divided by the number of plots in which the species was recorded. Percent presence, an expression of frequency, was the percent of plots in which each species occurred.

The planted spruce in the vegetation plots were compared to vegetation height and cover to assess whether these factors were associated with differences in seedling development.

The weighted averages of the fire effects data collected from triangles and plots (i.e., pre- and post-burn fuel loading and consumption, pre- and post-burn duff depth, depth of burn, and percent consumption) were determined to calculate a site average.

3 RESULTS AND DISCUSSION

3.1 Fire Effects

Canadian Forest Fire Weather Index System codes and indices at the time of burning (Van Wagner 1987) were: Fine Fuel Moisture Content (FFMC) = 90, Duff Moisture Code (DMC) = 44, and Drought Code (DC) = 314.

The pre-burn forest floor depth in the two triangles averaged 7.7 cm, depth of burn was 2.14 cm, and consumption was 27.8% (Table 16). Total woody fuel loading in the triangles was 107.5 tonnes/ha pre-burn and total consumption was 47.2%. Fine fuel consumption was 95.8% (Table 17).

TABLE 16 *Pre-burn and post-burn depth of forest floor, depth of burn, and percent consumption (mean and standard error)*

Pre-burn depth of forest floor (cm)	Post-burn depth of forest floor (cm)	Depth of burn (cm)	Consumption (%)
7.7 (1.6)	5.3 (1.0)	2.14 (0.46)	27.8 (0.40)

TABLE 17 *Total woody fuel loading and consumption (mean and standard error)*

Total pre-burn loading of all woody fuel (tonnes/ha)	Total consumption of all woody fuel (%)	Consumption of fine fuel (< 7 cm diameter) (%)
107.5 (6.2)	47.2 (2.3)	95.8 (4.2)

Actual forest floor consumption and mineral soil exposure were less than predicted by the Prescribed Fire Predictor (PFP) (Muraro 1975). Actual total woody fuel consumption (47%) was slightly greater than predicted for fuels < 22 cm in diameter (35%) (Table 18). The observed consumption of the fuel > 22 cm in diameter was generally less than that of the smaller pieces, whose consumption is expected to be even greater than 47%. The discrepancy between observed and PFP predicted values would have been even wider if that comparison could have been made.

TABLE 18 *Predicted and actual duff and fuel consumption and mineral soil exposure*

Duff consumption (%)		Mineral soil exposure (%)		Total woody fuel consumption (%)		Consumption of fine fuel (< 7 cm diameter) (%)	
Pred.[a]	Actual[b]	Pred.[a]	Actual[b,c]	Pred.[a,d]	Actual[b]	Pred.[a,c]	Actual[b]
60	27.8	50	31 (18.5 pre-burn)	35	47.2	80	95.8

a Predicted based on Prescribed Fire Predictor (Muraro 1975)
b Actual consumption of woody fuel and duff is estimated from fuel triangle measurements
c Predicted consumption of woody fuel < 22 cm in diameter
d Predicted consumption of woody fuel < 7 cm in diameter

3.2 Vegetation

3.2.1 Species diversity and autecology The number of species was greater in the tenth year after burning than in the first for all lifeforms except trees (Table 19). Diversity of shrub species almost doubled and of herb species almost tripled, although the latter may be somewhat inflated because the ability to identify species increased over time as the plants grew larger (Table 19). The apparent increase in the number of non-vascular plants in 1996 reflects the fact that specimens were identified by an expert for only that year.

TABLE 19 *Number of taxa by lifeform in each year*

	Lifeform				
Year	Trees	Shrubs	Herbs[a]	Non-vascular plants[b]	Total[b]
1987	1	6	16		23
1988	1	9	18	3	31
1989	1	10	22		33
1991	1	10	21	1	33
1996	1	11	36	16	64
Total per lifeform	1	11	45	17	742

a Includes graminoids

b Total number of taxa recorded over all years and lifeforms

Some of the shrub species present in the first year after burning resprouted from underground parts (i.e., *Rubus parviflorus, Lonicera involucrata, Oplopanax horridus*), others germinated from seeds (i.e., *Ribes laxiflorum, Ribes lacustre, Rubus idaeus*), while others used both strategies (i.e., *Sambucus racemosa*). *Amelanchier alnifolia* appeared to have established from seed. *Vaccinium* sp. was present prior to burning, but not observed after (Table 20).

TABLE 20 *Mean cover and percent presence of vegetation pre-burn and 1, 2, 3, 5, and 10 years after burning on the Brink site*

	Cover (%)						Presence (%)				
	Post-burn				Pre-burn		Post-burn				
Species	1987 plots	1988 plots	1989 plots	1991 plots	1996 plots	1986 triangles[a]	1987 plots	1988 plots	1989 plots	1991 plots	1996 plots
Trees											
Picea glauca × *engelmannii*[b]							PI	+	+	+	67
Shrubs											
Alnus viridis ssp. *sinuata*		1.67	0.03	0.67	1.67			33	33	33	33
Amelanchier alnifolia					0.17						33
Lonicera involucrata	0.83	2.33	0.37	1.83	2	P	67R	100	67	100	100
Oplopanax horridus			0.33	0.17	0.03	P			33	33	33
Ribes lacustre	0.03	0.33	0.07	0.5	0.2		33Sb	33	67	100	67
Ribes laxiflorum	0.17	0.33	0.07	0.13	0.1		33Sb	33	67	67	100
Rubus idaeus	3.67	7.67	7.03	5.5	3.7	P	100Sb	67	100	100	100
Rubus parviflorus	56.67	36.67	15	58.33	40	P	100R	100	100	100	100
Sambucus racemosa	0.67	3	0.67	0.67	0.03	P	100Sb	67	33	33	33
Sorbus sitchensis		0.33	0.33	1	1			33	33	33	33
Vaccinium sp.						P					
Viburnum edule		0.17	0.33	2	2.67			33	33	67	67
Herbs											
Actaea rubra	0.67						33				
Anaphalis margaritacea				0.5	0.33					67	67
Aquilegia sp.					0.03						33
Aruncus dioicus		2.5	0.7	1.33	1			67	67	67	67
Athyrium filix-femina	1.67	3.67	1.4	4.5	3.33	P	33R	67	100	100	100
Cornus canadensis	0.33	0.5	0.7	1.33	2.03	P	67	67	67	67	100
*Corydalis semperviren*s	2.37	0.17	0.07				100 S	33	67		
Crepis atribarba			0.03	0.17					33	33	
Crepis sp.[c]			0.03	0.03					33	33	
Epilobium angustifolium	7	7.33	15	11.67	8.33		100	100	100	100	100
Epilobium ciliatum	0.2	0.7	0.03				67Sb	100	33		
Equisetum arvense					0.03						33
Equisetum sylvaticum	1	7.33	1.03	0.33	0.23		100	100	100	67	100
Galium triflorum	0.2	0.07	0.07	0.4	0.1		67	67	67	100	100
Geranium bicknellii	6.67	0.2	0.03				67	67	33		
Gymnocarpium dryopteris	0.17	1.33	0.4	0.4	0.4		33	100	100	100	100
Heracleum lanatum					0.07						67
Hieracium albiflorum					0.53						100
Hieracium aurantiacum					0.2						67
Hieracium gracile					1						67
Hieracium sp.[c]		0.23	0.07	0.5	0.2			100	67	100	67
Lycopodium complanatum					0.03						33
Lycopodium selago					0.03						33
Maianthemum stellatum					0.33						33
Petasites frigidus var. *palmatus*					0.03						33
Rubus pedatus			0.03	0.07					33	33	
Stellaria sp.			0.03	0.07	0.03				33	33	33

TABLE 20 *Continued*

	Cover (%)					Presence (%)					
	Post-burn					Pre-burn	Post-burn				
Species	1987 plots	1988 plots	1989 plots	1991 plots	1996 plots	1986 triangles[a]	1987 plots	1988 plots	1989 plots	1991 plots	1996 plots
Streptopus roseus	0.33	0.73	0.07	0.4	0.53		67	100	67	100	100
Taraxacum sp.				0.07	0.33					67	67
Thalictrum occidentale		1.03	0.07	0.83	0.17			67	67	67	33
Tiarella trifoliata ssp. *trifoliata*	0.5	0.37	0.07	0.33	0.17		67	67	67	67	33
Urtica dioica	0.33	2.33	0.33	0.33	0.03		33	33	33	33	33
Veratrum viride	0.67	2.33	1	2	1	P	33R	33	33	33	33
Graminoids						P					
Agrostis scabra					0.03						33
Agrostis sp.					0.17						33
Calamagrostis canadensis[f]	5	8.33	6.67	13.33			33	33	33	33	
Carex aenea					0.03						33
Carex deweyana					0.03						33
Carex mertensii					0.03						33
Carex rossii					0.03						33
Carex sp.[h]	6.83	5.67	2.03	1.33			100Sb	100	100	100	
Poaceae #5[g]					0.5						67
Poaceae #6[g]					0.37						33
Poaceae #7[g]					0.17						33
Poaceae #8[h]					0.03						33
Non-vascular plants[i]											
Amblystegium serpens					0.03						33
Brachythecium salebrosum					0.1						100
Brachythecium sp.		0.03			0.03			33			33
Bryum caespiticium					0.1						100
Ceratodon purpureus					0.1						100
Cladonia coniocraea					0.03						33
Cladonia fimbriata					0.03						33
Eurhynchium pulchellum					0.03						33
Leptobryum pyriforme					0.03						33
Marchantia polymorpha		0.03			0.03			33			33
Peltigera canina					0.03						33
Peltigera rufescens					0.03						33
Plagiomnium ciliare					0.07						67
Polytrichum juniperinum				0.67	0.1					33	100
Polytrichum sp.		0.03						33			
Roellia roellii					0.07						67
Timmia austriaca					0.03						33
TOTAL	75	81.67	82.5	91.67	91.67		100	100	67	100	100

a Indicates presence as the dominant species (by J. Muraro)
b Spruce was planted adjacent and within the plots in 1986
c Mode of establishment (MOE): R = established by resprouting, S = established from seed, Sb = established from seed bank, Pl = planted
d This is likely *Crepis atrabarba*
e This is likely one or more of *Hieracium albiflorum*, *H. aurianticum*, or *H. gracile*
f It is likely that one of the unidentified grasses in 1996 was *Calamagrostis canadensis*
g These are members of the Poaceae family that could not be identified beyond the family level; numbers refer to the specimen number
h This is likely one or more of *Carex aenea*, *C. deweyana*, *C. mertensiana*, or *C. rossii*
i Specimens were identified by an expert in 1996

The increase in herbs between the first and fifth years was mainly due to the establishment of "weedy" species with wind-dispersed seeds, while those that first appeared in 1996 occur in all seral stages, including mature forests. Many herbs observed after burning (i.e., *Athyrium filix-femina, Gymnocarpium dryopteris, Cornus canadensis,* and *Tiarella trifoliata* ssp. *trifoliata*) are typical of mature forests, and were likely present before the site was logged. The three herb species present in the first post-burn year (1987) but gone by the fifth (*Geranium bicknellii, Epilobium ciliatum, Corydalis sempervirens*) are typical ephemeral species with long-term seed dormancy (Table 20).

3.2.2 Changes in abundance, composition, and structure Total percent cover increased from around 75% in the first post-burn year and levelled off at 92% 5 years after burning (Figure 25). Non-vascular plants recovered very slowly to pre-burn levels, while planted spruce trees slowly increased their cover to about 15%, capitalizing on the decrease in herb and shrub cover.

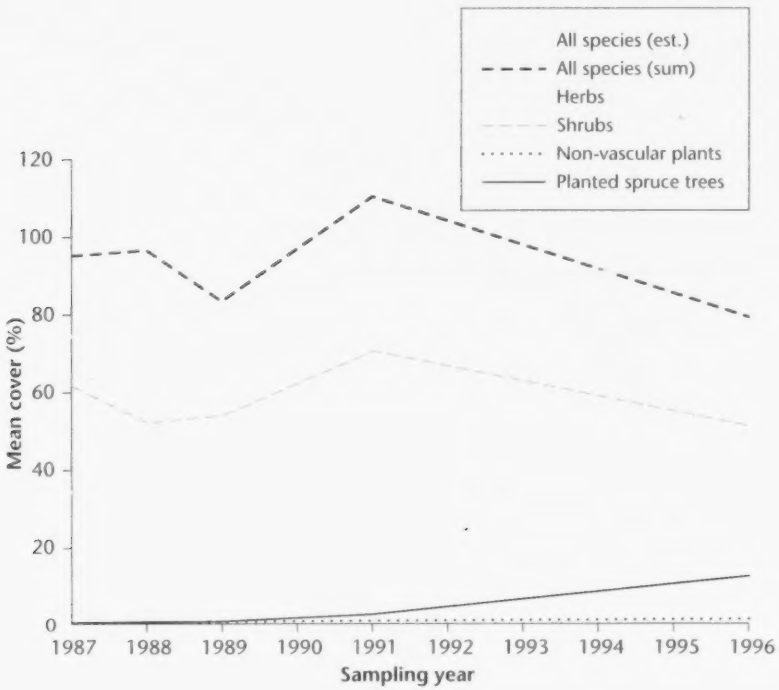

FIGURE 25 *Estimated mean sums of percent cover by lifeform and total, estimated total percent cover, and calculated planted spruce percent cover for the Brink site.*

Shrubs were more abundant than herbs in all sampling years (Figure 25). The shrub layer was dominated by *Rubus parviflorus*; no other shrub species covered much of the site (Figure 26). This species was present before the burn and expanded rapidly post-burn. *Alnus viridis* ssp. *sinuata*, a new species on the site with relatively low abundance, increased in abundance over time, growing to around 3 m tall. *Lonicera involucrata*, also sparse, grew taller over time (Figure 27). Both *Rubus idaeus* and *Sambucus racemosa* showed rapid height growth initially, then gradually declined as seed bank germinants died (Figure 27).

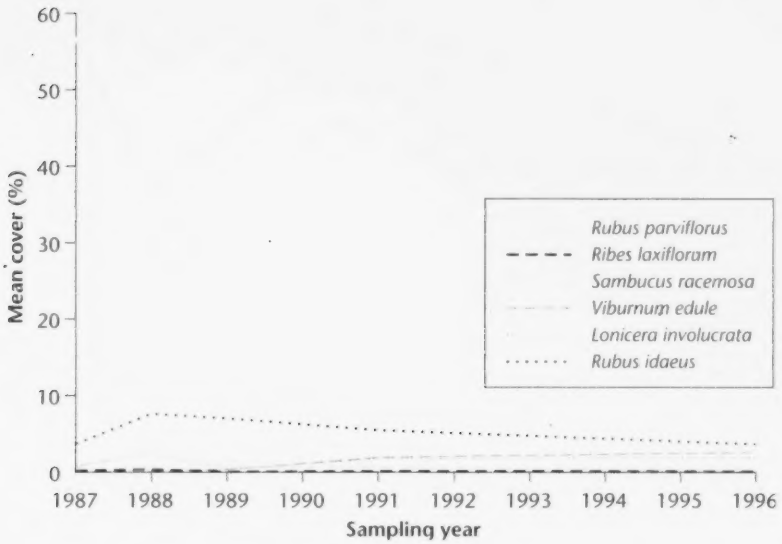

FIGURE 26 *Estimated mean percent cover of selected shrubs over time.*

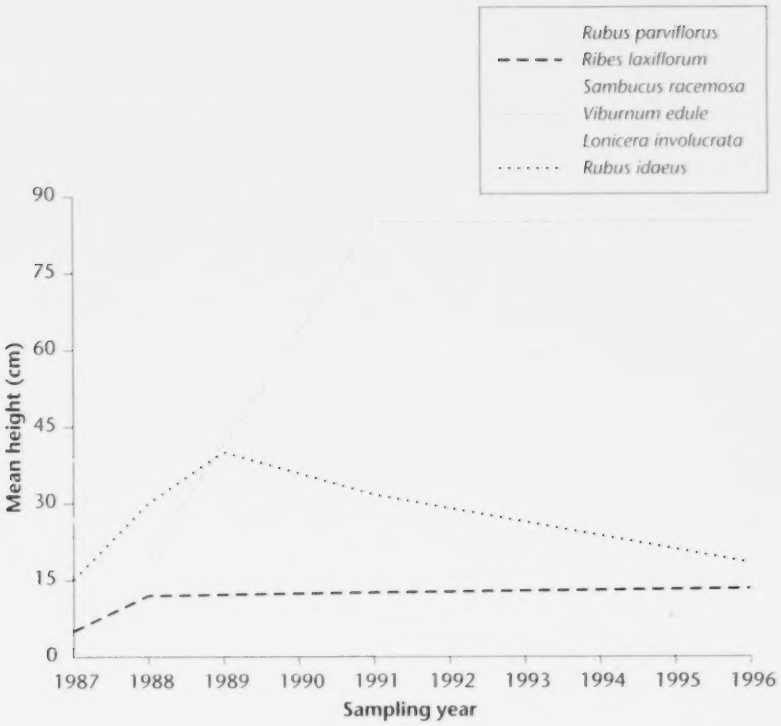

FIGURE 27 *Estimated mean height of selected shrubs over time.*

In the first 2 years after the site was burned, *Epilobium angustifolium* and *Calamagrostis canadensis* dominanted the site (Table 20; Figures 28 and 29). By year 10, *Calamagrostis canadensis* and other grasses had almost disappeared, *Epilobium angustifolium* was in decline, and *Athyrium filix-femina* was the second-most abundant herb. Most other herbs maintained relatively low cover.

By the tenth year after burning, planted spruce seedlings were beginning to cover a substantial proportion of the site (Figure 25). We expect this species to overtake shrubs in influencing the structure, species composition, and abundance of the understorey vegetation as it becomes the dominant species.

3.3 Planted Conifers

There was no mortality among the 15 trees that were measured. The large stock planted on this site, along with a relatively high burn severity, appears to have contributed to the high survival of planted trees. Average seedling height at the time of planting was 34 cm, average root collar diameter was about 1 cm, and average canopy area was 110 cm^2. By 1996, average tree height was 236 cm, average root collar diameter was 6 cm, and average canopy area was 1.2 m^2. Despite the rapid re-establishment and high cover of *Rubus parviflorus*, it did not appear to have adversely affected the planted spruce. The planted trees were twice as tall as the other vegetation by the fifth post-burn year, indicating that most were probably free-growing by that time. By the spring of 1997, 10 years after planting, planted trees were five times the height of the other vegetation.

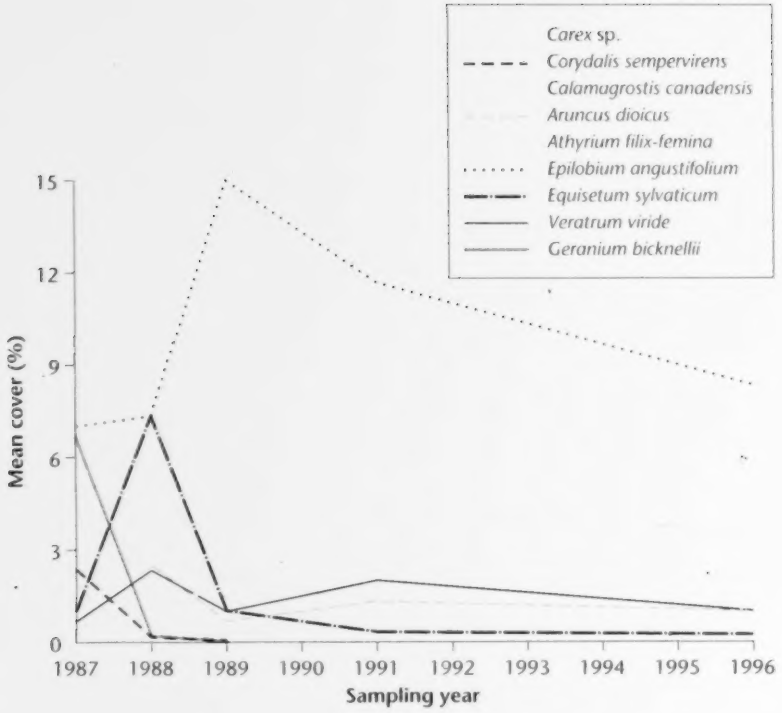

FIGURE 28 *Estimated mean percent cover of selected herbs over time.*

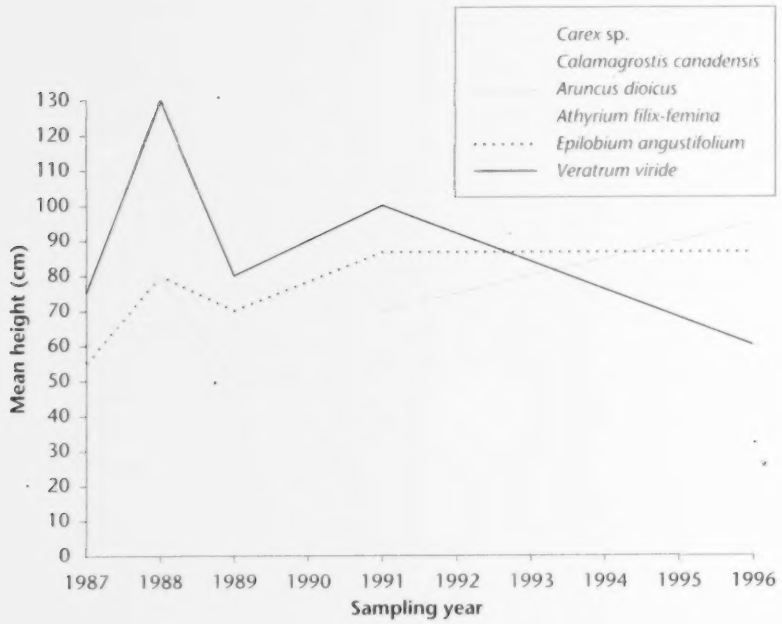

FIGURE 29 *Estimated mean height of selected herbs over time.*

4 CONCLUSIONS

The main conclusions of this study are:

- The fire was of moderate severity, consuming almost half of the total fuel, almost all of the fine fuel, and close to 28% of forest floor.
- The relatively high Drought Code (314) suggests that the deep forest floor layers were quite dry at the time of burning.
- Forest floor consumption and mineral soil exposure were less than predicted by the PFP, and woody fuel consumption was greater than predicted.
- The consumption of a high percentage of the forest floor led to significant mineral soil exposure, which facilitated the establishment of invasive species.
- Burning stimulated the germination of buried seeds of several species, including numerous berry-producing shrubs that are important for wildlife.
- Most of the native vascular plants on this site were sufficiently adapted to survive burning, since at least some individuals survived and resprouted.
- Some native plant species are detrimentally affected by fire and the exposed conditions found in cutblocks.
- Species adapted to open conditions (e.g., *Epilobium angustifolium*) proliferated in the open cutblock.
- Ten years after burning, the site was dominated by planted spruce trees, *Rubus parviflorus*, *Rubus idaeus*, *Epilobium angustifolium*, and *Athyrium filix-femina*. *Rubus idaeus* and *Epilobium angustifolium* continue to decline, while the others have increasing or fluctuating cover values over time.

5 RECOMMENDATIONS

- Better calibration of the CFFWIS and Prescribed Fire Predictor for British Columbia conditions.
- Synthesis of fire effects, succession, and reforestation data from similar ecosystems in British Columbia.
- Continued monitoring of sites to ensure the collection of long-term data.

Abstract Fire effects and vegetation and seedling responses to burning were monitored for 5 years after slashburning. A fire weather station was established, and fuel consumption and burn severity were determined using fire effects assessment triangles and permanent plots. Changes in floristic composition and structure (percent cover and height) were documented. The burn was of fairly low severity. Fuel consumption was greater than predicted by the Prescribed Fire Predictor, while duff consumption and mineral soil exposure were somewhat less than predicted. After the site was logged and burned, the ground-level vegetation structure shifted from a community dominated by bryophytes and small herbs to a young conifer forest with taller herbs and shrubs. Some of the original forest species were lost. A number of new species established from the seed bank and sources outside of the plot.

1 INTRODUCTION

1.1 Background and Rationale

Clearcutting and slashburning have been widely practised in British Columbia, but little is known about subsequent patterns of vegetation development or how management activities, particularly slashburn severity, influence these patterns. The strong positive response to FRDA Report 018 (Hamilton and Yearsley 1988) indicates that predictive models of forest vegetation succession are essential for developing management prescriptions that meet such integrated resource use objectives as forest regeneration, providing wildlife habitat, and maintaining biodiversity. The information will also contribute to the development of a seral classification within the biogeoclimatic ecosystem classification (BEC) system.

This site is one of several in the Sub-Boreal Spruce (SBS) zone where vegetation is being monitored after clearcutting and slashburning. The study is among very few in British Columbia to record slashburning severity and collect several years of post-burn data on all vegetation species in permanent plots. Although similar data are being collected on several sites in the Northern Interior Forest Region, and a number of other chronosequence and combined studies have been done, very little of this information has been published. Results from our sites will be combined to form the basis of a preliminary report on early forest succession in the SBS zone, and will be compared to the patterns derived from a set of similar sites we are monitoring in the ESSF zone.

1.2 Objectives

The objectives of this study are:

1. to document the effects of a prescribed slashburn on the forest floor, fuels, and vegetation;
2. to determine the relationships among predicted and actual fuel and duff consumption and mineral soil exposure on this site; and
3. to quantify and describe changes in percent cover, height, species composition, and diversity of vegetation following burning.

2 METHODS

2.1 Study Area

This site (Cutting Permit 19147, Opening number 93H 043-40) is located in the Prince George Forest District of the Northern Interior Forest Region, southeast of Prince George (Figure 1). The block is situated at approximately 950 m elevation in the Sub-Boreal Spruce (SBS) zone in the very wet cool subzone (SBSvk). The site is at 53°26′37″ N, 121°33′03″ W, and was classified within the SBSvk/02 (*Pinus contorta* var. *latifolia*—*Vaccinium membranaceum*—*Vaccinium myrtilloides*) site series.

The site was clearcut in the winter of 1985–86 when snow cover was deep enough to prevent disturbance of the forest floor and destruction of understorey vegetation on most of the site. The site was burned on June 13, 1986 and planted in 1987. It was sampled for 5 years, until the site was treated with herbicide, after which observations were discontinued.

2.2 Data collection

Three 5 × 5-m permanent plots were established in the summer of 1987 after slashburning. The plots were established at the mid-point of each side of one of the two operational fire effects assessment triangles installed on the site following standard procedures (Trowbridge et al. 1994) (Figure 30). Depth of burn (DOB) and fuel consumption were recorded by J. Muraro and a field crew. A fire weather station was established on the site and the data were used to calculate Canadian Forest Fire Weather codes and indices (Van Wagner 1987).

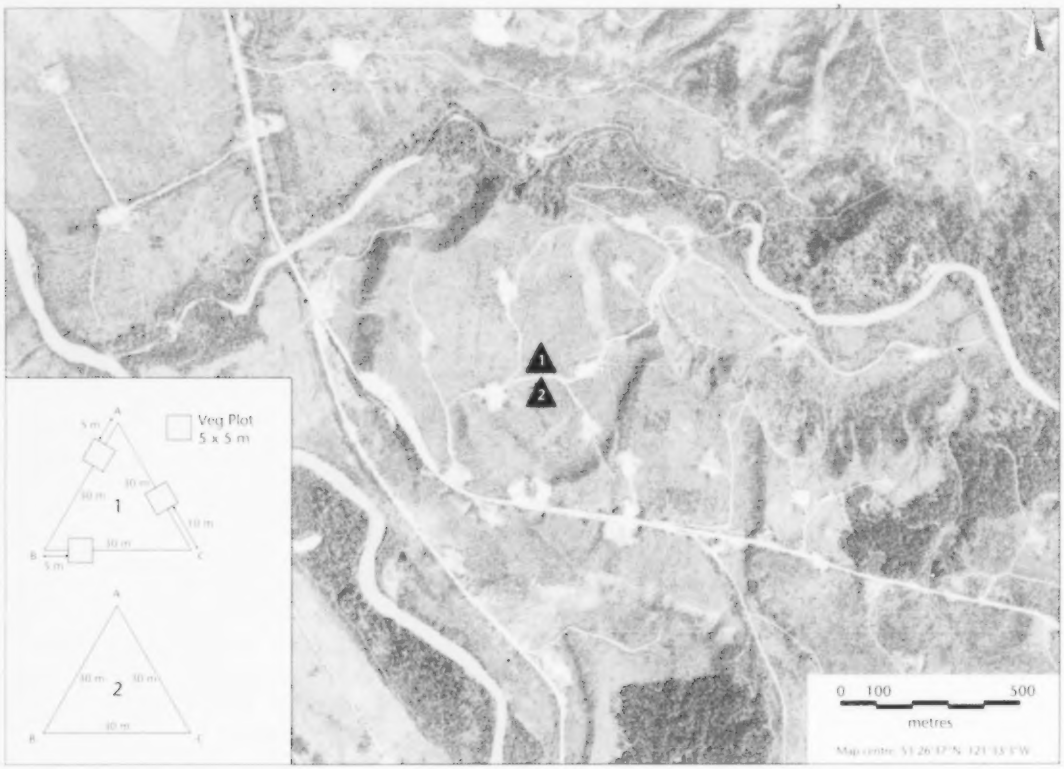

FIGURE 30 *Orthophoto of the site and layout of vegetation plots and fire effects assessment triangles on the site.*

2.2.1 Fire effects Two fire effects assessment triangles (30 m per triangle side, for a total of 180-m of line-intersect sampling) were installed on the site by J. Muraro and his crew following standard methods (Trowbridge et al. 1986). Depth of burn (DOB) pins were installed at 5-m intervals along all three sides of the triangles, except at the vertices (30 pins/triangle, or 60 in total).

The DOB and remaining duff depth were measured at each pin after burning. Woody fuel loading was estimated prior to burning and consumption was determined by resampling the transects after the fire.

2.2.2 Vegetation Presence of the key plant species in the triangles was recorded just prior to burning by J. Muraro and his crew. Complete vascular species vegetation data were collected from each plot in July or August of 1987, 1988, 1989, and 1991 (1, 2, 3, and 5 years after burning). Mean height was collected for selected herb and shrub species. The mode of establishment, either from seed or resprouting from surviving plant parts, was recorded in 1987 for selected species.

Percent cover was defined as an estimate of the actual area covered by projecting the leaves of the species onto the ground. Percent cover for all species combined (total) was also recorded in the field, but lifeform totals for herbs and shrubs were never recorded. Non-vascular plants are included in the total percent cover estimates.

Height was recorded for selected herbs and all shrubs and, in some years, all species combined (total). Only vascular plants are included in the total height values since non-vascular plants contributed little to the above-ground structure of forest vegetation. Height was estimated as the average height of a species in the plot, taking into account the proportion of the cover of individual plants with different heights. This was done by taking several measurements where there was substantial variation, and estimating the mean. For example, if 5% of the species cover was 150 cm tall but the rest was only 90 cm tall, then the estimated height was much closer to 90 cm than to 150 cm.

Since heights were recorded for all shrub species, it was possible to generate a mean height for this lifeform using the following formula, which weights the height by cover:

$$\text{mean shrub height} = \frac{\sum_{\text{shrub species } s}^{\text{all shrub species}} (\%\ \text{cover}_s) \times (\text{mean height}_s)}{\sum_{\text{shrub species } s}^{\text{all shrub species}} \%\ \text{cover}_s}$$

Trees were not included in the calculations for shrub height. Average herb height could not be calculated because not all species were measured.

Lodgepole pine and spruce were both planted on the site. Twenty planted lodgepole pine trees were tagged, and height, root collar diameter, and canopy width and breadth were measured at the time of planting and during subsequent sampling.

2.3 Data Analysis

Pre-burn vegetation data were compared to the appropriate units in the provincial biogeoclimatic ecosystem classification (BEC) database and a draft version of the field guide update for the Northern Interior Forest Region (DeLong 2003) to confirm the site series classification.

The data collected from this site did not employ a formal experimental design. Therefore, graphs and descriptive statistics, rather than formal analyses, are used to present and assess the changes in vegetation and planted spruce over time.

Mean percent cover was calculated as the sum of the cover values for a given species, divided by the total number of sample plots to provide a measure of abundance over the whole site. Mean height was calculated as the sum of the heights recorded for a species, divided by the number of plots in which the species was recorded. Percent presence, an expression of frequency, is the percentage of plots in which each species occurred.

3.1 Fire Effects

Canadian Forest Fire Weather Index System codes and indices (Van Wagner 1987) estimated prior to burning were: Fine Fuel Moisture Content (FFMC) = 85, Duff Moisture Code (DMC) = 13, and Drought Code (DC) = 96.

The pre-burn forest floor depth in the two triangles was 6.4 cm, of which 2.54 cm was comprised of litter and moss. The depth of burn (DOB) was 0.6 cm and forest floor consumption was 9.4% (Table 21). The moss and litter layer was quite thick on this site, and the fire consumed some of it. There was also some consumption of the underlying F and H horizons.

Total woody fuel loading in the triangles was 81.4 tonnes/ha pre-burn, and total consumption was 35.2%. Fine fuel consumption was 75.3% (Table 22). This burn was classified as low severity.

TABLE 21 *Pre-burn litter depth, pre-burn and post-burn depth of the forest floor, depth of burn, and percent consumption of the forest floor (mean and standard error)*

Source	Pre-burn litter depth (cm)	Pre-burn depth of forest floor (cm)	Post-burn depth of forest floor (cm)	Depth of burn (cm)	Consumption of forest floor (%)
Site total (n = 60 DOB pins)	2.54 (0.04)	6.4 (0.10)	5.8 (0.23)	0.6 (0.09)	9.4 (1.2)

TABLE 22 *Total woody fuel loading, total consumption, and fine fuel consumption (mean and standard error)*

Source	Total pre-burn loading of all woody fuel (tonnes/ha)	Total consumption of all woody fuel (%)	Consumption of fine fuel (< 7 cm diameter) (%)
Site total (180 m of transect)	81.4 (1.9)	35.2 (9.5)	75.3 (0.84)

Actual forest floor consumption and mineral soil exposure were slightly less than predicted by the Prescribed Fire Predictor (PFP) (Muraro 1975). Actual total woody fuel consumption was greater than predicted for fuels < 22 cm in diameter (Table 23). The PFP predicts total fuel consumption by size class for pieces up to 22 cm in diameter. The data collected on consumption were not broken down by size classes for pieces > 7 cm in diameter. The consumption of fuel > 22 cm in diameter was generally less than that of the smaller pieces. Therefore, consumption of woody fuel < 22 cm in diameter would have been higher than that observed, and the discrepancy between observed and PFP-predicted values would have been wider, if that comparison could have been made.

TABLE 23 *Predicted and actual duff and fuel consumption and mineral soil exposure*

Duff consumption (%)		Mineral soil exposure (%)		Total woody fuel consumption (%)		Consumption of fine fuel (< 7 cm diameter) (%)	
Pred.[a]	Actual[b]	Pred.[a]	Actual[b]	Pred.[a,c]	Actual[b]	Pred.[a,d]	Actual[b]
15[a]	9.4	10	5	5	35.2	40	75.3

a Predicted based on Prescribed Fire Predictor (Muraro 1975)
b Actual consumption of woody fuel and duff and mineral soil exposure are estimates based on two fuel triangle measurements
c Predicted consumption of woody fuel < 22 cm in diameter
d Predicted consumption of woody fuel < 7 cm in diameter

3.2 Vegetation

The number of shrub and herb species increased over time. This reflects improvements in the ability to identify species (as they grew larger and flowered) as well as actual increases in species diversity. Pre-burn data are incomplete and based on key species noted as present pre-burn and on species that resprouted in 1987, immediately post-burn. This number should be considered as the minimum number of taxa present pre-burn (Table 24).

TABLE 24 *Number of taxa by lifeform in each year*

	Lifeform			
Year	Trees	Shrubs	Herbs[a]	Total
1987	3	4	7	14
1988	3	4	10	17
1989	3	3	14	20
1991	3	3	14	20

a Includes graminoids

Planted lodgepole pine and hybrid spruce trees and suckering trembling aspen increased rapidly in percent cover, height, and frequency and were the dominant vegetation on the site by year 5 (Table 25; Figure 31).

TABLE 25 *Mean cover, percent presence, and mode of establishment pre-burn and 1, 2, 3, and 5 years post-burn at the Indianpoint site*

	Cover (%)				Presence (%) and mode of establishment					
	Post-burn				Pre-burn			Post-burn		
Species	1987 plots	1988 plots	1989 plots	1991 plots	1986 triangles[a]	1986 plots	1987 MOE[b]	1988 plots	1989 plots	1991 plots
Trees										
Picea engelmannii							Pl			
Pinus contorta var. *latifolia*					P		Pl			
Populus tremuloides	3.3	8.3	13.3	15	P	33	R	33	33	33
Shrubs										
Amelanchier alnifolia					P					
Lonicera involucrata					P					
Oplopanax horridus					P					
Rosa sp.					P					
Sambucus racemosa	0.03					33	Sb			
Sorbus sitchensis		0.7			P			33		
Spiraea betulifolia	0.17	0.3	0.3	0.3	M	33	R	33	67	67
Vaccinium membranaceum	0.07	0.5	0.2	0.2	P	67	R	67	33	33
Vaccinium myrtilloides	0.03	1.4	1.5	4.8	P	33	R	100	100	100
Herbs										
Anaphalis margaritacea				0.3						67
Calamagrostis canadensis		1						33		
Carex sp. (likely *aenea*)	10	13.3	17.3	30		100	Sb	100	100	100
Cinna latifolia			0.2	0.07					33	33
Cornus canadensis	0.07	0.7	0.5	0.8	M	67	R	33	67	67
Corydalis sempervirens	2.17	1.7	0.7			100	Sb	100	100	
Crepis sp.				0.03						33
Epilobium angustifolium	0.37	4	12.7	7.8	P	100	R/S	100	100	100
Epilobium ciliatum	0.17	0.53	0.5			33	Sb	100	100	
Hieracium scouleri			0.3	0.4					67	67
Hieracium sp.		0.4						100		
Hieracium #1[c]			0.8	0.5					100	100
Lycopodium annotinum	0.17	0.03	0.2	0.03	M	33	R	33	33	33
Maianthemum canadensis		0.7	0.8	2.3				100	100	100
Orthilia secunda					P					
Poaceae #2[c]			0.2	0.2					33	33
Poaceae #3[c]			0.2	0.2					33	33
Streptopus lanceolatus var. *curvipes*	0.37				M	100	R			
Taraxacum sp.		0.03	0.3	0.1				33	67	67
Viola sp.			0.2	0.03					33	33
Mosses										
Dicranum sp.			0.2	0.2					33	33
Polytrichum sp.		0.7	0.5	1.3				67	67	67
Moss sp.			0.2	0.2					33	33
TOTAL	16.9	34.3	51.0	64.9						

a P indicates presence of dominant species based on pre-burn sampling in two triangles by fire effects assessors in 1986

b Mode of establishment (MOE): R = established by resprouting, R/S = established by resprouting and by seed, Sb = established from seed bank, Pl = planted

c These are members of the Hieracium genus and Poaceae families that could not be identified beyond that level; the numbers refer to the specimen number

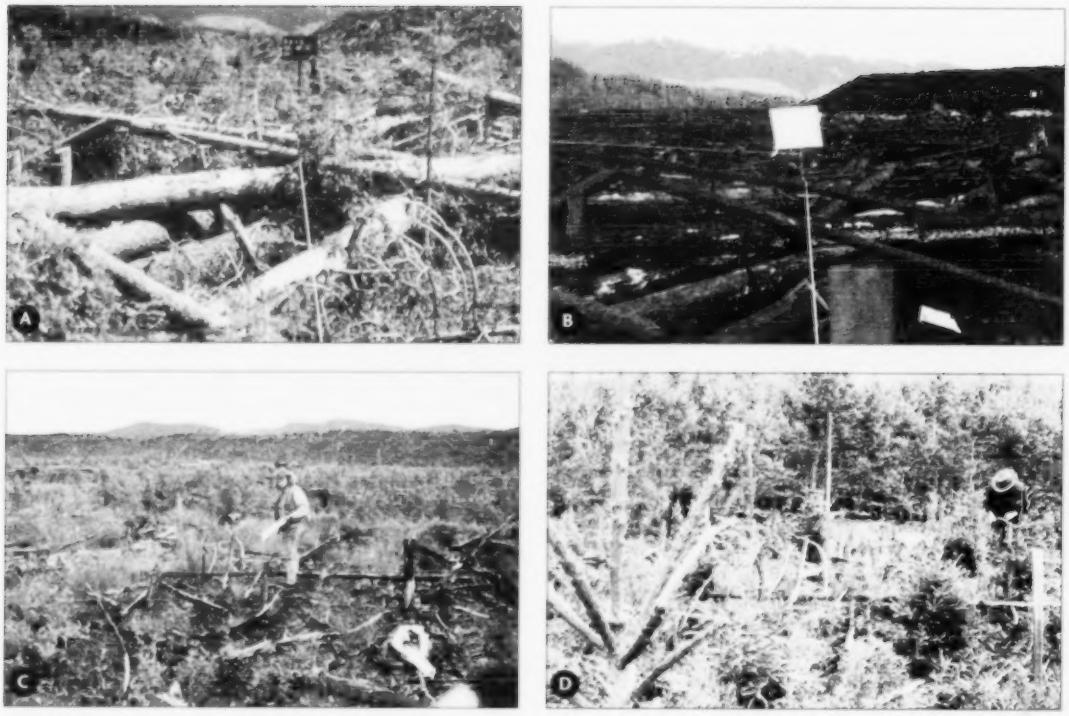

FIGURE 31 *Photos of the site (A) pre-burn, (B) immediately after burning, (C) 2 years after burning, and (D) 5 years after burning.*

Some of the shrub species noted as present in the triangles (but not necessarily in the plots) prior to burning (i.e., *Vaccinium membranaceum* and *V. myrtilloides*) resprouted after the fire (Figure 32). *V. myrtilloides* increased in cover and frequency over time (Figure 32). Some species noted as present in the triangles pre-burn (i.e., *Amelanchier alnifolia, Lonicera involucrata, Rosa* sp., and *Oplopanax horridus*) were not found in the plots post-burn, which may reflect their vulnerability to burning. *Sorbus sitchensis* was observed pre- and post-burn. *Spiraea betulifolia* was not recorded pre-burn, but must have been present since it resprouted the year after burning (Figure 32). Germinants of *Sambucus racemosa* established from buried seeds, although they did not appear to have survived for long (Table 25).

After the fire, species typical of the forested successional stage, such as *Cornus canadensis*, *Calamagrostis canadensis*, and *Lycopodium* sp. re-established. New species germinated from buried seeds (i.e., *Carex* sp., *Corydalis sempervirens*, and *Epilobium ciliatum*), and new species typical of open habitat (e.g., *Hieracium* sp., *Anaphalis margaritacea*, *Crepis* sp., and *Taraxacum* sp.) dispersed from wind-dispersed seeds. The three new species that established from the seed bank are ephemeral in habit with long-term seed dormancy. *Carex* sp. was quite abundant the first year after burning, indicating the presence of an extensive seed bank. *Corydalis sempervirens* and *E. ciliatum* were short-lived, while *Carex* sp. persisted (Figure 33). *Carex* sp. and *E. angustifolium* dominated the herb layer. By year 5, *Epilobium angustifolium* was in decline while *Carex* sp. continued to increase in abundance (Table 25; Figure 33).

4 CONCLUSIONS

Actual fuel consumption was greater than that predicted, while the actual forest floor or duff consumption was somewhat less than predicted. Although the fire was of low severity, there was a dramatic change in post-burn floristic composition. *Epilobium angustifolium* quickly dominated the site. Some of the original shrubs survived, although others apparently could not tolerate this low-severity fire. Several herbs with dormant seed banks proliferated after the fire, and numerous "weedy" species invaded. Conifer and trembling aspen growth were rapid on the site.

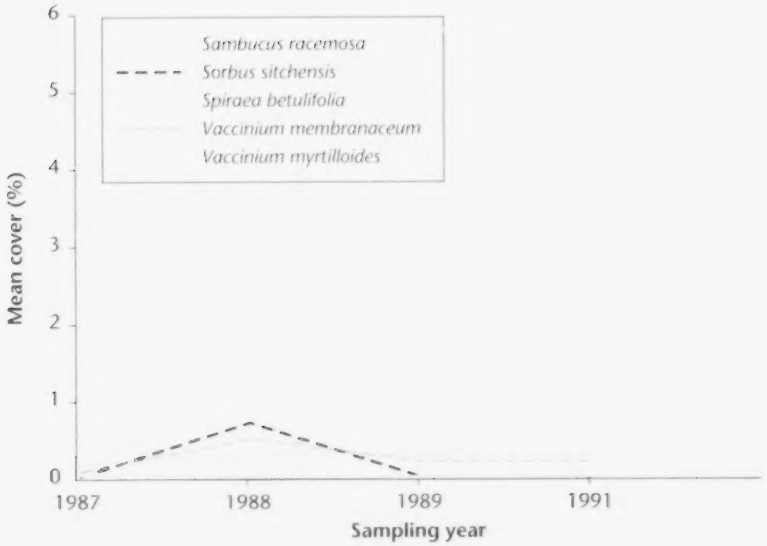

FIGURE 32 *Estimated mean percent cover of selected shrubs over time.*

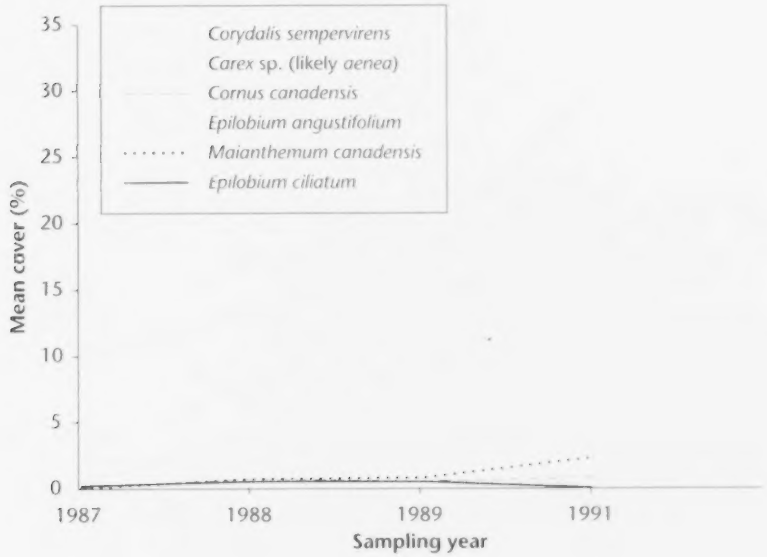

FIGURE 33 *Estimated mean percent cover of selected herbs over time.*

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APPENDIX *List of scientific and common names of plants, by lifeform.*

Lifeform	Scientific name[a]	Common name[a]
Trees	*Picea glauca* × *engelmannii*	hybrid white (interior) spruce
Shrubs	*Alnus viridis* ssp. *sinuata*	Sitka alder
	Amelanchier alnifolia	saskatoon
	Lonicera involucrata	black twinberry
	Oplopanax horridus	devil's club
	Ribes lacustre	black gooseberry
	Ribes laxiflorum	trailing black currant
	Rubus idaeus	red raspberry
	Rubus parviflorus	thimbleberry
	Sambucus racemosa	red elderberry
	Sorbus sitchensis	mountain-ash
	Viburnum edule	highbush-cranberry
Herbs	*Actaea rubra*	baneberry
	Anaphalis margaritacea	pearly everlasting
	Aquilegia sp.	columbine species
	Aruncus dioicus	goatsbeard
	Athyrium filix-femina	lady fern
	Cornus canadensis	bunchberry
	Corydalis sempervirens	pink corydalis
	Crepis atrabarba	slender hawksbeard
	Crepis sp.	hawksbeard
	Epilobium angustifolium	fireweed
	Epilobium ciliatum	purple-leaved willowherb
	Equisetum arvense	common horsetail
	Equisetum sylvaticum	wood horsetail
	Galium triflorum	sweet-scented bedstraw
	Geranium bicknellii	Bicknell's geranium
	Gymnocarpium dryopteris	oak fern
	Heracleum lanatum	cow-parsnip
	Hieracium albiflorum	white hawkweed
	Hieracium aurantiacum	orange hawkweed
	Hieracium gracile	slender hawkweed
	Hieracium spp.	hawkweed species
	Lycopodium complanatum	ground-cedar
	Lycopodium selago	club moss
	Petasites frigidus var. *palmatus*	palmate-leaved coltsfoot
	Rubus pedatus	five-leaved bramble
	Maianthemum stellatum	star-flowered false Solomon's-seal
	Stellaria sp.	starwort
	Streptopus lanceolatus var. *curvipes*	rosy twistedstalk
	Taraxacum officinale	common dandelion
	Thalictrum occidentale	western meadowrue
	Tiarella trifoliata var. *trifoliata*	three-leaved foamflower
	Urtica dioica	stinging nettle
	Veratrum viride	Indian hellebore

APPENDIX *Continued*

Lifeform	Scientific name[a]	Common name[a]
Graminoids	*Agrostis scabra*	hair bentgrass
	Agrostis sp.	bentgrass species
	Calamagrostis canadensis	bluejoint
	Carex aenea	bronze sedge
	Carex deweyana	Dewey's sedge
	Carex mertensii	Merten's sedge
	Carex rossii	Ross' sedge
	Carex sp.	sedge species
	Poaceae	unknown grasses
Non-vascular plants	*Amblystegium serpens*	creeping feathermoss
	Brachythecium salebrosum	golden ragged-moss
	Brachythecium sp.	ragged-moss
	Bryum caespiticium	tufted thread-moss
	Ceratodon purpureus	fire moss
	Cladonia coniocraea	lesser powderhorn
	Cladonia fimbriata	powdered pixie-cup
	Eurhynchium pulchellum	elegant beaked-moss
	Marchantia polymorpha	green-tongue liverwort
	Peltigera canina	dog pelt
	Peltigera rufescens	felt pelt
	Plagiomnium ciliare	
	Polytrichum juniperinum	juniper haircap moss
	Polytrichum sp.	haircap moss
	Rhacelia roellii	mountain moss
	Timmia austriaca	false polytrichum

a Nomenclature follows the British Columbia provincial species list (B.C. Ministry of Forests 2004)